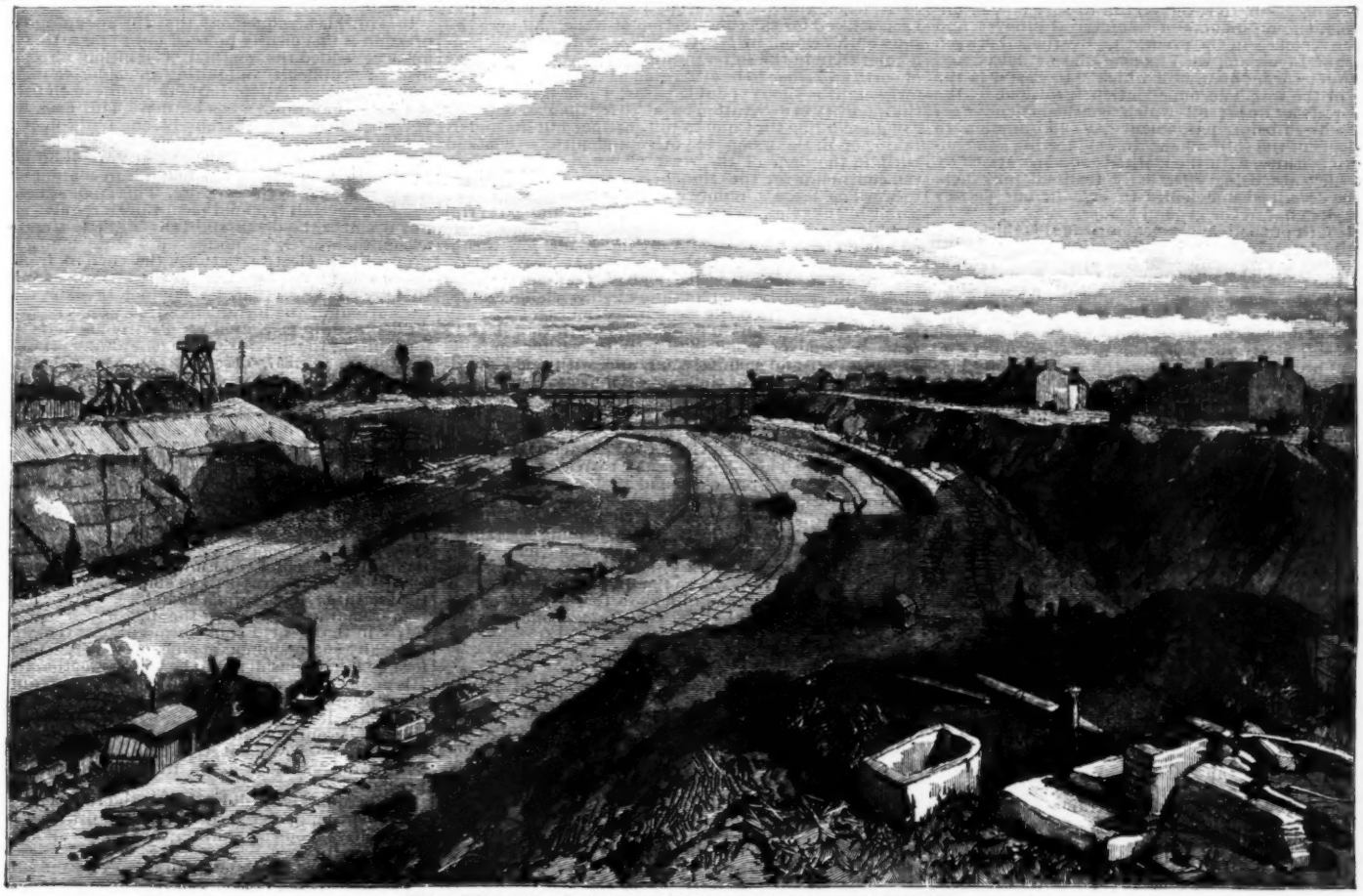
SCIENTIFIC AMERICAN

No. SUPPLEMENT. 715

Scientific American Supplement, Vol. XXVIII., No. 715
Scientific American, established 1845.

NEW YORK, SEPTEMBER 14, 1889.

Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.



THE WORKS AT LATCHFORD, NEAR WARRINGTON.

THE WORKS AT EASTHAM, ON THE MERSEY ESTUARY.

THE MANCHESTER SHIP CANAL.

THE MANCHESTER SHIP CANAL.

THE approaching completion of the most important parts of the great works from Manchester to the estuary of the Mersey, and the successful performance, so far, of engineering designs which underwent a prolonged controversy and repeated parliamentary inquiry till three or four years ago, and which the contractor, Mr. T. A. Walker, is carrying into execution by the employment of a vast amount of labor, with the aid of an extraordinary apparatus of machines, must be regarded as a matter of much public interest. Our special artist, Mr. W. Simpson, whose illustrations of this project, and of the localities through which the ship canal was to pass, appeared in *The Illustrated London News* of February 3, 1883, and further on July 17, 1886, has recently again visited the banks of the Irwell and the Mersey, for the purpose of making sketches of the actual progress of these works. It will not be needful, upon this occasion, to revert to the history of the undertaking, the arguments of commercial interest and local convenience in its favor, the relations between the port of Liverpool, with its magnificent docks, and the manufacturing district of which Manchester is the center, or the traffic accommodation furnished by the several railway lines; all which considerations were fully discussed before parliament gave its sanction to the scheme of the ship canal. Its engineering and constructive features, with the methods and operations by which they are being effectually realized, may here again be described sufficiently to explain our artist's present sketches to the general reader.

The length of the Manchester ship canal is thirty-five miles; its depth is 26 ft.; and the minimum width at its bottom is 120 ft. This is 48 feet wider than the bottom of the Suez canal, while the depth is equal; so that the largest cargo steamers can pass each other in the Manchester ship canal. At several points, near the locks and near the docks, this canal is wide enough for such ships to turn. For a length of three miles and a half, approaching Manchester, the width at the bottom is 170 ft., so that ships can lie outside the docks along the wharves on the Salford side. There will also be open side basins, if required, or widenings at shipbuilding yards, or where cargoes are discharged or loaded, for manufacturing establishments or storehouses adjoining the canal.

Five sets of locks—at Eastham, on the Mersey sea estuary; at Latchford, on the Mersey, above Warrington; at Irlam, above the junction of the river Irwell with the Mersey; at Barton, on the Irwell; and at Manchester—raise the level of the canal, on the whole, 60 ft. above the sea. Of its entire length, twenty-three miles, inland from Runcorn to Manchester, will have been formed by cutting a straight and deep channel for the rivers Mersey and Irwell. The lower section, from Eastham to Runcorn, forms a curved line of twelve miles along the Cheshire shore of the broad inner expanse of the Mersey estuary; but at Weston Point, meeting the estuary of the navigable river Weaver, which is connected with an extensive system of canals, it will obtain valuable local traffic, especially the shipment of salt. A large trade with Cheshire and the Staffordshire potteries, by the Bridgewater canal, will also reach the ship canal at Runcorn, as well as that of the chemical manufactures at Widnes. The Shropshire Union canals will feed the traffic at Ellesmere Port, near Eastham.

The Manchester docks, formed on both banks of the Irwell, chiefly in Salford, but also in Manchester on the site of the Pomona Gardens, Cornbrook, and extending to Throstlenest and the Albert Bridge, near the Old Trafford Road, will afford ample accommodation to the trade of that city. They occupy a space of two hundred acres. The water area of the dock basins is sixty-two acres and a half, and the quay frontages are three miles and a half in aggregate length, to which may be added a mile of open wharves along the wide part of the canal just below; and there will be two miles and a half of the canal bank, lower down, available for discharging cargoes into barges and lighters, and putting them ashore. Fifty hydraulic cranes, some of great power, will be provided at the Manchester and Salford docks.

The docks at Warrington, twenty-two acres and a half in extent, are not yet constructed: they will have a railroad connection with the London and North-Western and the Great Western Railway, which will bring a large coal and general traffic.

At Runcorn, at the head of the Mersey estuary, the docks belonging to the Bridgewater Canal Navigation, having been purchased by the Manchester ship canal, will always be accessible, instead of being entered only at spring tides as hitherto; the local trade advantages here, as well as those of the docks at Weston Point, for the Weaver navigation, have already been noticed.

The ship canal will be entered from the sea, or rather from the Mersey estuary, about four miles above Birkenhead, by the tidal locks at Eastham, all the gates of which will be open at high tides. The sills of these entrances will be 11 ft. lower than the deepest dock sills at Liverpool or Birkenhead; and the channel approaching them will be dredged 3 ft. deeper than the lock sills.

Such will be the Manchester ship canal, omitting for the present a detailed description of the docks at Manchester and Salford. The engineer, Mr. Leader Williams, C.E., and Mr. J. A. Walker, the contractor, have been wonderfully successful in their operations; and there is no doubt of the work being finished before the end of the year 1891, having been commenced in November, 1887. The contract was taken by Mr. Walker for £5,750,000, but we may expect this sum to be considerably exceeded by the total cost of the ship canal; for the purchase of the Bridgewater canal property has cost £1,750,000. One of the great causes of expense has been the erection or reconstruction of railway bridges crossing the canal, each at a high elevation, to give a clear headway of 75 ft. above the water, and with the approach lines of railway to rise by moderate gradients on each side. The Cheshire Lines Railway at Iriam, the Wigan Junction line, the Warrington and Stockport line, the Grand Junction line at Warrington, and the London and North-Western Railway at Runcorn, must be treated with such costly alterations. The Barton aqueduct of the Bridgewater canal across the Mersey is replaced by an opening swing bridge, which is an iron trough, to be closed at each end when the bridge is to be opened, and to contain the water of the Bridgewater canal, held thus safely above the level of the ship canal. There will be hydraulic lifts by which laden barges can easily be transferred from the one canal to the other. The locks on the ship canal are not single, but each set of locks has receptacles of different sizes for vessels of different classes, to avoid the waste of water in using a lock much larger than the size of the vessel requires. The canal level descends 16 ft. at the Trafford locks, near Manchester, 14 ft. at the Barton locks, 14 ft. at the Irlam locks, again at Latchford, 16 ft. more, and finally at Eastham, to the level of the sea. The largest lock at Eastham is 600 feet long and 80 feet wide.

The line of the canal is cut through flat country, marsh meadows chiefly, pretty straight beyond the junction of the Irwell and Mersey, avoiding the many windings of those rivers, which are generally turned into a new artificial channel, somewhat to the south of the old left bank of each river. In a few places only, on the Mersey, where the ground is higher, the cuttings are 50 ft. deep, and partly through sandstone, which has been utilized for the construction of walls, and here the sides of the canal, being of rock, are made more perpendicular than in the softer ground. The whole quantity of earth and stone to be excavated has been computed at forty-eight millions of cubic yards, which is more than the quantity of excavation required for the Panama ship canal, including the Culebra hill cutting; but the undertaking of M. De Lesseps has other difficulties to contend with, in the dam of the river Chagres. Mr. Walker, the contractor for the Manchester ship canal, has set to work as large a number of men, not negroes, but English "navvies," with more numerous and powerful machines, and with about one-tenth the expenditure of money, and he will certainly finish his job within the appointed time. It is stated that nearly 15,000 hands are employed, with eighty steam excavators of four different kinds, pumping engines, steam cranes, and 150 locomotives, for which 200 miles of railway have been laid down, to remove the earth that is dug out. A scene of wonderful activity, with admirable organization and management, and with good provision for the welfare of the industrial army, is now to be witnessed everywhere between Manchester and Eastham.

Our artist's pictures will be regarded with interest. The first now given is a view of the canal at Latchford, looking east. This place is near to Warrington, and about half way from each end of the canal. There are to be locks here; and the wide excavation shown in this view is the space in which the docks will be constructed. The view at Eastham, looking east, shows what has been accomplished at the other end, where the canal joins the Mersey at Eastham. This deep cutting is at the spot where the first set of locks are to be made, which will be quite close to the west or seaward end of the canal.—*The Illustrated London News.*

ON GAS ENGINES.*

By EDWARD DELAMARE-DEBOUTTEVILLE, of Rouen.

Historical.—Nearly a century has elapsed since the appearance of the first definite description of a gas engine; and many years passed before this ingenious idea was practically developed into a working machine. No sooner had the first gas motor become an accomplished fact, than improvements rapidly suggested themselves, and contributed to insure its success. It is not intended to review in detail the numerous inventions relating to gas engines; but it will be of interest to note those which have been conspicuous by the importance of their results. From the 31st of October, 1791, when John Barber published the first description of a gas engine, until the 24th January, 1860, when Lenoir brought out his well known arrangement, thirty-eight patents were taken out in France and elsewhere; and in glancing through these old documents it is surprising to recognize in them all the ideas which are supposed to have originated only yesterday, besides others which may turn out to be the success of to-morrow.

Since the later date nearly 700 patents have been taken out, and from an examination of these it would seem as though there were nothing further left to invent; nevertheless, each year gives rise to ideas that are new in their application, even if not novel in themselves. Such efforts cannot fail to result in a radical change of the former plans. Up to 1860 the various inventors may be said to have worked in ignorance of one another's doings, and their designs clearly show that their ideas were original with themselves, and that their efforts were directed, not to the improvement of previous inventions, but to the search after combinations which they supposed to be new. But when the first gas engines were got practically to work, the new ideas followed the current of the time. The inventors who followed Lenoir set themselves to improve the double-acting engine; now they are endeavoring to apply the four-cycle plan of Beau de Rochas. Is this arrangement likely to be final? Will no better plan be discovered for rendering the gas engine a successful rival of the steam engine? As yet it is impossible to answer so intricate a question; but pending some radical change, it is possible to improve existing engines, and to simplify their construction and working. Until very recently the gas engine has been specially applied where only small power is required; its application for such powers as have hitherto been considered the province of steam is reserved for the future. A rapid examination of the most important inventions since 1791 will enable a notion to be formed of what has already been done and of what still remains to be accomplished. At that date gas was not an industrial product, and accordingly John Barber described what he considered the best processes for its production. He proposed to distill coal, wood, oil, or other combustibles in a retort, and then by means of a pump to inject the product into a cylinder where explosion takes place. A second pump injects air in suitable proportions, and ignition is effected by the flame of a match or candle. To avoid excessive heating, he proposed the injection of water by a pump.

Although Barber's machine could never have been a practical success, it is interesting as the first idea of an engine driven by explosive gas. Three years later Robert Street described a gas engine consisting of a cylinder and piston, with a slide valve containing the flame for igniting the explosive mixture, which he produced by allowing a few drops of oil of turpentine to fall on the bottom of a cylinder superheated by a stove, while the piston, raised by the flywheel, sucked in air, and the latter combining with the vapor of turpentine rendered it explosive. The flame in the slide valve ignited the mixture, whereby the motive power was produced.

William Barnett's invention, dated April 18, 1838, shown in Fig. 1, marks an important step in the history of gas engines. He describes three kinds of motor, the first single-acting and the second double-acting, while the third and most interesting is on the compression principle. In this last the gaseous mixture was admitted on both sides of the piston. Two pumps, driven at twice the speed of the motor, compressed the air and gas separately; and the compressed air and gas were mixed in the cylinder at the end of each stroke, and were there ignited. A third pump was used for clearing the cylinder of the burnt gases after their expansion.

It is in this arrangement that the advantage of compression is first clearly pointed out; and to this novelty must be added the method of ignition also. Recognizing the difficulty of igniting an explosive mixture in a state of compression, Barnett proposed to use a hollow cock containing a gas burner. This cock has a revolving movement, whereby in one position it brings the burner into contact with an external flame which lights it, and in its further motion shuts it off from the external air, and brings its flame into contact with the compressed gas in the cylinder. This mode of conveying the flame certainly could not insure a regular ignition, but it marks the first step in that direction, and on this account is worthy of notice. John Reynolds, in 1844, proposed an electric battery, the current from which was to heat a platinum wire to incandescence, and thereby cause ignition. A contact breaker transmits the current at the instant required.

Shepherd, in 1850, used an electro-magnetic machine for igniting the mixture. Eugene Barsanti and Felix Matteucci, in 1857, described an atmospheric motor (Fig. 2), the precursor of the Otto & Langen engine, which it closely resembled in external appearance, although as a practical success it was by no means all that could be desired. The only detail worthy of special notice is the employment of a Bunsen battery, connected with a De la Rive multiplier, the sparks from which caused the ignition. Subsequently in the Lenoir engine, the De la Rive multiplier was replaced by a Ruhmkorff coil. In 1858 and 1859, Degrand gave descriptions of a whole series of engines of different types, and in particular a four-cycle compression engine is minutely specified; but unfortunately the mechanical details which he proposed to employ are not of a practical nature. This brings us to 1860, which will always be a remarkable year in the history of gas motors. Early in that year Lenoir brought out the first commercially successful gas engine, of which he may therefore be fairly considered to be the first actual inventor. His engine (Fig. 3) is too well known to require any description; but it is interesting to remark that in its final form it embodied six successive additions to the original invention; and it is only by studying this long course of improvement that the ingenuity of the inventor and the merit of his invention can be fairly appreciated.

Unfortunately he did not reap the full success which his invention deserved, its two chief drawbacks being a defective mode of ignition and an extravagant consumption of gas. No sooner was Lenoir's engine brought to public notice than it became the subject of lively discussion, not only in regard to its practical advantages and disadvantages, but especially as concerned the scientific conditions of its working. A fresh stimulus was given to inventors, but their efforts were no longer confined to fresh combinations of details more or less novel, but were directed to new conditions of working. Many fresh cycles of operation were suggested, but their description in detail would be too lengthy. One specification, however, is worthy of particular notice, not only on account of its special bearing on the subject of this paper, but also for the remarkable clearness with which the scientific conditions of a rational mode of working are laid down, and the precision with which the author has stated in detail how the conditions required to attain the most economical result are to be realized. In 1862 M. Beau de Rochas published a specification dealing in detail with several scientific questions. Those only which relate to the gas engine will here be considered, but as fully and completely as possible. The theories broached by him have already led to remarkable results in practice, and a more careful study of them will probably be repaid by many further improvements. Neglecting the non-compression motor, we come at once to that in which compression is adopted; but before proceeding to describe the arrangements by which he proposes to fulfill the conditions theoretically required, M. Beau de Rochas lays down the law that there are four such conditions necessary to realize the best results from the elastic force of gas: 1, the cylinders should have the greatest capacity with the smallest circumferential surface; 2, the speed should be as high as possible; 3, the cut-off should be as early as possible; 4, the initial pressure should be as high as possible. 1. For a given expenditure of gas the greatest diameter of cylinder will correspond with the most effective utilization of heat. Therefore, whenever possible, only one cylinder should be employed for each distinct motor. 2. But time is a factor in the dissipation of heat. Other things being equal, the slower the speed, the greater will be the loss of heat. For the same power a greater speed means a smaller cylinder; but the antagonism between this and the last named condition vanishes if it is remembered that for a given expenditure the proportion between the stroke and the capacity of the cylinder need not always be the same. 3. In a gas engine, just as in one actuated by steam or other elastic vapor, the greatest range of expansion gives the best result. But under the conditions last stated the maximum range is limited by the circumstances of each special case. Therefore, that arrangement which allows the freest range of expansion, or in other words, which permits the earliest cut-off practicable, will give the best result. 4. Lastly, the utilization of the elastic force of gas depends on another element connected with the advantage of a high grade of expansion.

This element is the pressure, which to give the best result should be as high as possible. It is evident that

* Paper read before the Institution of Mechanical Engineers, at Paris, July 3, 1889.

it is a question of expansion in a heated state after compression in a cold state, or of increasing the expansion by a method inverse to that which consists in creating a vacuum: such an inverse method would not be applicable to steam, since all compression must involve a corresponding condensation, so that, even if steam were combustible, instantaneous heating would thereby be rendered impossible.

The fundamental idea of M. Beau de Rochas is thus clearly seen to consist in the compression of the gaseous mixture to the greatest extent practicable before ignition. Manifestly the only way to do this is to use a single cylinder, first on account of the advantage of having as large a one as possible, and next to minimize the resistances of the mixture. Consequently, for one end of the cylinder, the following sequence of operations takes place during four consecutive strokes: *a*, inspiration during an entire stroke; *b*, compression during the second (return) stroke; *c*, ignition at the dead point and expansion during the third stroke; *d*, expulsion of the burnt gas during the fourth (return) stroke. This engine, he claims, fulfills the condition of the largest possible cylinder, and the still more important condition of initial compression. Moreover, the speed of the piston in proportion to its diameter is the greatest possible, since the work usually performed in two strokes is accomplished in one. In 1863 Mr. Hugon brought out his motor, in which ignition was effected by a gas flame controlled by a slide; the arrangement was ingenious, but the motor had only a moderate success.

In 1867, at the Paris exhibition, Messrs. Otto & Langen brought out their atmospheric motor (Fig. 4), bearing a strong resemblance to that of Barsanti & Matteucci. Its construction was ingenious, and its working a practical success. The rack and clutch motion was worthy of special notice, the slide valve was ingenious, and the increased economy of consumption considerable; but its working was both noisy and violent. A description of this engine was given to the Institution in 1875 (Proceedings, page 191). The Bischoff motor (Figs. 5 and 6) appeared in 1870, but its success was confined to engines of very small power, of which a large number were made. It would probably have been still more extensively adopted, had it not been for the Otto engine, which was brought out six years later, in 1876. Dr. Otto's inventions were two in number; the first (Fig. 7), in 1876, related to two kinds of engines—one without and one with compression; while the other, in 1877, had reference to improvements in the slide valve and other details of the compression engine; and this type of engine alone need now be discussed, as at the present time the non-compressing engine may be considered to be abandoned, on account of its excessive consumption.

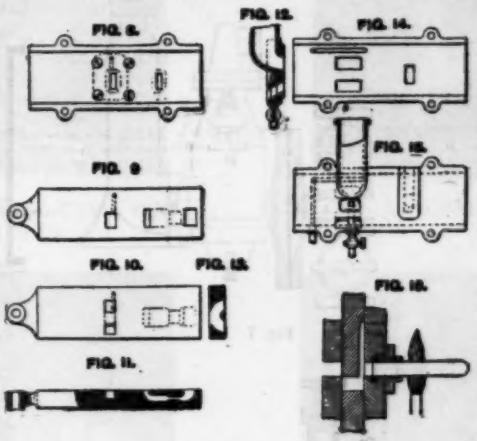
The fundamental idea of the engine is based on the four-cycle principle of Beau de Rochas, already described. In connection with his 1876 invention, Dr. Otto enunciated a special theory, which has been called the theory of the threefold mixture. The mixture was composed—first of a portion of the products of combustion from the preceding stroke; secondly of a modicum of pure air allowed to enter at the commencement of the admission; and thirdly of a combustible mixture of air and gas admitted afterward.

This threefold mixture resulted in a less violent explosion, a successive combustion of one molecule after another, more regular and more silent working, and great economy in consumption. This theory, which, owing to the limited knowledge of the subject at that time, was accepted without question, can no longer be admitted, as its fallacy is demonstrated by every-day practice.

As these theories have been refuted by the most competent authorities on the subject, they may be passed over; but though Dr. Otto has thus been unfortunate from the scientific point of view, from a practical point few inventors have achieved so decided a success, and for many years he was the only maker of gas engines. The Otto engine is so well known to engineers that any detailed description, beyond the general fact that it is a single-acting motor on the four-cycle principle, would be superfluous; but the method of ignition, as described by him in 1877, requires a more careful study; and a critical examination of this, and of the more important of the methods previously used, seems indispensable to the present subject, as the improvements introduced by the author were the direct outcome of a similar study.

Ignition.—The arrangement for ignition in the Otto engine consists of an external flame placed against the cover of the slide, and of a port pierced in the bottom of the cylinder for the admission of the gaseous mixture and for its ignition; above this port (Fig. 8) is another small hole, by which an equilibrium is maintained between the gases in the cylinder and those in the slide. On one side the slide carries a spreader for effecting the intimate mixing of the gas and air, and in its central part a chamber, where ignition takes place (Figs. 9, 10, 11, and 13). By a special arrangement this chamber is filled with a mixture of air and gas in suitable proportions, the slide is moved, the interior chamber is exposed to the external gas burner (Figs. 12, 14, and 15), and its charge ignited. As the speed of the slide is suitably proportioned, the flame in its cavity is carried forward and communicated to the compressed mixture in the cylinder. It will, of course, be understood that by this movement of the slide all communication with the outer air is now cut off, so that the flame in the ignition cavity is protected from any external influence. If this momentary flame were at once brought into contact with the compressed mixture, it would be blown out by the violent current set up; but this is avoided by an ingenious arrangement.

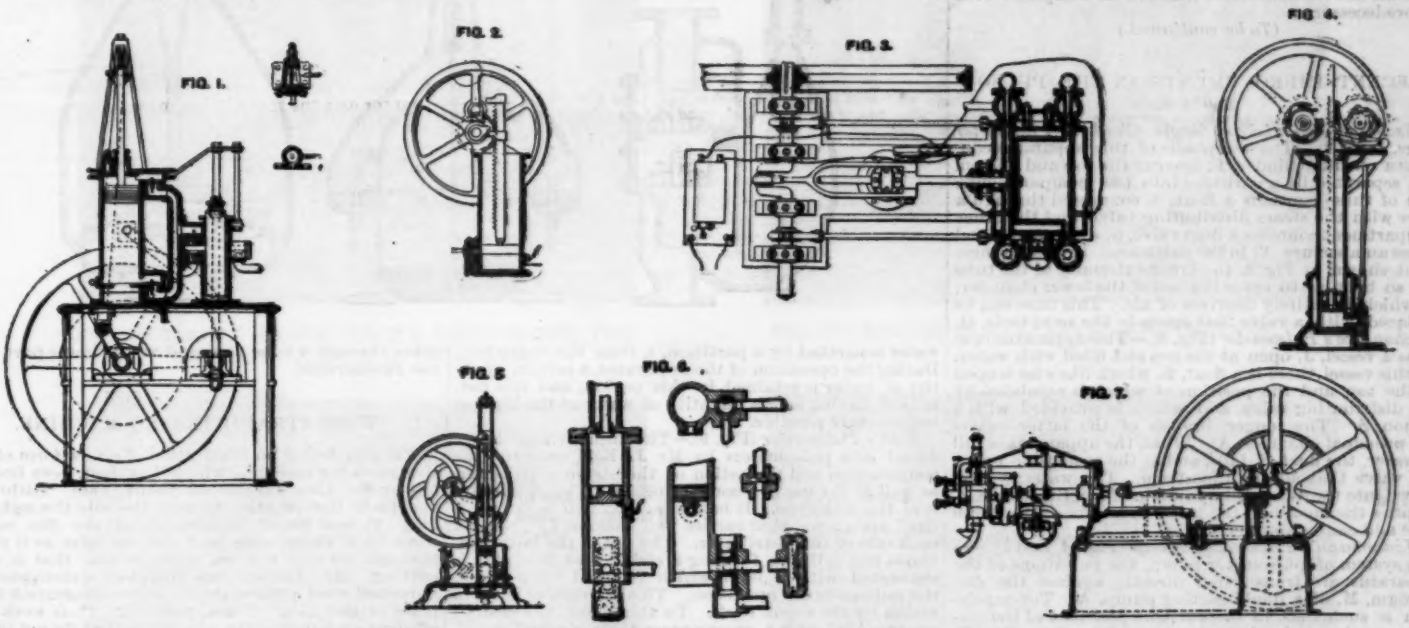
The small hole previously mentioned, which is situated in the slide face at the bottom of the cylinder, is slightly in advance of the port proper, so that it comes line and line with a similar hole in the valve itself before the port is uncovered. This second hole forms a communication with the interior of the ignition chamber, so that a minute volume of the compressed gases from the cylinder entering thus into an enlarged space is partially expanded, and revives the inner flame when just at the point of extinction. At this instant the port of the slide comes line and line with that of the cylinder, and as the pressure of the ignited mixture in the cavity of the slide has been thus progressively but considerably increased, there is no fear of its extinction, or of its failing to ignite the charge in the cylinder.



As an additional precaution, the orifice at the bottom of the cylinder is filled, by a special arrangement, with a mixture richer in gas, and it is by this richer mixture, containing none of the products of combustion of the previous stroke, that the interior flame is re-enforced, as has just been described. This system, however, is very complicated. It depends on numerous orifices, which become rapidly incrusted, owing to the flame which fills them at the moment of ignition. A layer of carbon is deposited on their inner surfaces, and soon attains a considerable thickness. To insure the equilibrium of pressures with sufficient delicacy, the cut-off edges must be adjusted to a small fraction of a millimeter, and however accurately this may be done at first, it is soon modified by the incrustations above named, which must be frequently removed, if the best result is to be obtained. In addition, the slide, reduced as it is in thickness by the interior cavity, is easily buckled by the heat of the flame, and its efficiency impaired. The temperature of the slide superheated by the interior and exterior flames is very high, and burns the oil on the slide faces, and the combination of these two defects causes frequent seizing. Bearing in mind what a delicate operation must be the transporting of a flame in so confined a space, it is no matter of surprise that however accurate the original adjustment may be, misfires are of pretty frequent occurrence, arising either from failure to ignite at the outside burner, or from premature extinction of the inside flame, or from the absence of perfect balance at any moment; and these mis-fires must detract from the efficiency of the engine.

When a rich gas, such as is used for domestic purposes, is employed, ignition, which depends, as has been shown, upon the equilibrium of pressures, is tolerably regular, because such gas is easy to light; but with a poor gas the problem becomes more difficult, and for this reason its employment has not made much progress. A much stronger flame is required to insure the ignition of a poor mixture with any degree of certainty. With a large engine, starting becomes an operation of great nicety when the flame has to be conveyed, because, if the slide does not travel with sufficient rapidity, the flame is burnt out before reaching the charge in the cylinder; and it is no easy matter to impart sufficient initial velocity to a flywheel of any considerable weight. An examination of the Lenoir system of 1860, which has since been repeatedly copied, discloses still more serious defects, and these defects were obvious from the first, since all subsequent inventors, including Dr. Otto, have been compelled to adopt an actual flame as more certain and less troublesome. Lenoir's igniting arrangement was as follows: an insulator, containing a platinum wire, was fixed at each end of the cylinder, and another platinum wire was fixed inside the cylinder, with its extremity at a short distance from the first. The two wires were respectively connected with the positive and negative poles of a Ruhmkorff coil, through which a battery sent its current, and a spark passed from point to point. At a given moment, the circuit was completed by a key, the spark transmitted, and the mixture fired. The circuit was then interrupted, and again made at the next revolution of the engine. At first sight this appears an excellent arrangement, but it is not found to work well in practice. The following is what takes place: At the commencement of each stroke a condensation of aqueous vapor takes place, while the metal is taking up heat; the interior platinum points are covered with moisture, and the spark is transmitted only at intervals, or even not all, causing difficulty in starting and irregularity in running. Again, the points may become coated with the oil used for lubrication, with an equally objectionable result. Lastly, the points, immersed as they are in the explosive mixture, become incrusted with carbon, and the current is intercepted. Another cause of irregularity occurs in the interrupter itself, as follows: If it could be arranged that, at the moment the key touched the plate, contact was made and the mixture ignited, and that such contact should only be made at the exact moment required, ignition would be regular; but it is well known that the current through the coil may become so intensified as to pass between the key and the plate at 10 mm., 15 mm., or even 18 mm. distance, causing ignition at irregular periods. To avoid this as far as possible, interrupters acting suddenly were adopted; but these rapidly wore out, and were inevitably of a complicated nature. At first sight this would seem to be an insignificant objection, as it might be thought that a variation in the moment of ignition corresponding with a variation of only from 10 mm. to 18 mm. distance between the points of the contact would be of no practical account; but a comparison of the diagrams taken with these variations shows a considerable difference; it is surprising to note the difference in the indicated power when the moment of ignition varies by even so little as $\frac{1}{10}$ of a second. There is also the liability to an accident which the author has twice met with in his early trials. One pole, say the negative, is in direct communication with the engine itself, so that the whole machine is negatively electrified, and it may happen that at any moment, although the positive current has not been switched on, a spark may pass, and the mixture be ignited prematurely, before the crank has passed the center. During a course of experiments on all the systems of ignition known, the paramount importance of a thoroughly good ignition has been conclusively proved. For safe working, it is indispensable to have a perfectly certain ignition, powerful enough to explode a poor gas, and free from the objections above indicated. As a matter of fact, there are only the two principles of an actual flame and of electricity; the choice therefore is confined to the various applications

VARIOUS GAS ENGINES.



of these two methods; and as a powerful ignition is a condition of immense importance, this condition is only fulfilled by the electric spark. All the methods of ignition by flame have proved inferior to it in this respect, including the superheating of a platinum wire by a flame, and the expedient of raising a thin tube to a red heat.

The latter is an old expedient which was fully described by Mr. Leo Funck in 1879 (Fig. 16); it gives a regular ignition, but is not free from inconveniences, the chief being that the heat of the tube never equals that of the electric spark, and the plan is consequently not so applicable where poor gases are used, while the tubes themselves deteriorate so rapidly that they are destroyed in the course of a few hours. This is the result of the high pressure produced within the cylinder at the moment of ignition, when the white hot tube is externally exposed only to atmospheric pressure; the compressed gas is admitted inside the tube, and a still higher pressure, with a tendency to burst the tube, is produced by ignition. If, to avoid this, the tube is made thicker, it does not attain the white heat requisite for good ignition. Lastly, the tube is internally cooled by the partial expansion of the compressed gas admitted to its interior, and this decrease in temperature still further reduces the chances of a good ignition. If a valve is employed to regulate the moment of ignition within the tube, there is the further risk of a premature explosion, tending to reverse the direction of revolution of the flywheel. This might be caused by the valve not bearing properly on its seat at the required moment, thus allowing the passage of a thin stream of compressed gas, which would be prematurely ignited. It might appear that the ill effect of the difference between the internal and external pressures could be simply avoided by placing the tube inside the cylinder, but this would entail even greater objections. The tube carrier would require to be removed whenever it required to be freed from the incrustation caused by the products of combustion; it would suffer rapid deterioration from the high internal temperature; there would always be the fear of premature explosions; and with this arrangement, after every stoppage a secondary system of ignition would be necessary until the internal tube had been brought to a white heat, thus involving two processes instead of one.

The use of a platinum wire raised to incandescence by the electric current still remains to be considered. As in the case of the hollow tube just described, there is the advantage of the cooling of the wire at the moment of the introduction of the gaseous mixture, and consequent irregularity of ignition. Even without this fault, it is easy to see that the heating power of a wire raised to a white heat must be inferior to that of a strong spark which is not affected either by cooling action or by violent currents of air. The author will now proceed at once to describe the Simplex motor, and to point out its distinctive features as compared with its predecessors.

(To be continued.)

RECENT IMPROVEMENTS IN THE PULSOMETER.

Fischer & Schonicke's Single Chamber Pulsometer (Figs. 1 and 2).—The receptacle of this apparatus contains a central cylinder, F, open at the top and bottom and separated by a partition into two compartments. One of these contains a float, S, connected through a lever with the steam distributing valve, and the other compartment contains a float valve, S, which opens and closes an aperture, V, in the partition. In the arrangement shown in Fig. 2, the lower extremity of the tube 2 is so bent as to enter the top of the lower chamber, F, which it entirely deprives of air. This tube can be replaced with a valve that opens in the receptacle, G.

Schonicke's Pulsometer (Fig. 3).—This apparatus contains a vessel, J, open at the top and filled with water. In this vessel there is a float, S, which likewise is open at the top, and the position of which is regulated by the distributing valve, and which is provided with a siphon, Z. The longer branch of the latter enters the principal chamber, A. When the apparatus is full of water, the float, S, falls, and at the same time opens the valve that admits the steam. The water is then forced into the ascensional column. Then the siphon, Z, empties the float, and the latter again closes the steam pipe and causes another suction.

Haussmann's Pulsometer Pump (Figs. 4 and 5).—In this system of pulsometer pump, the pulsations of the apparatus are transmitted directly against the diaphragm, M, of a doubl-eacting pump, A. The regulation is such that, in the extreme positions of the diaphragm, the work of the force and lift pulsometer, D, is not yet finished. The temperature and volume of water of the pulsometer are regulated through the suction valve, S, the delivery valve, R, and the safety valve, S, which may be replaced with a waste pipe of corresponding height.

In an improved form of this apparatus (Fig. 5) the exit of hot water in excess in the steam chamber takes place, not after the diaphragm has taken its most remote position toward the left, but rather during the forcing period, so that the flow of hot water through the delivery valve, R, which communicates through a conduit with the steam chamber, D, takes place at the beginning of the period of compression and ceases when the diaphragm has reached its extreme position. The entrance of cold water into the steam chamber, D, during the period of suction takes place through the valve, S, and is so regulated that the necessary quantity of water has reached D when the diaphragm has attained its corresponding extreme position.

Winkelmann's Single Chamber Pulsometer (Fig. 6).—A trumpet-shaped tube, D, debouches in the force chamber, C, and its narrow extremity ends in front of the orifice that admits steam, where it is held by projecting pieces fixed to the body of the apparatus. It results from this arrangement that, in the forcing period, water is projected by the tube, D, to meet the steam, which latter condenses. The entrance of steam is thus suspended, and a vacuum is produced to effect a suction.

A clack manœuvered from the exterior, through a hand wheel, permits of regulating the quantity of water injected through the tube, D.

Klein's Pulsometer (Figs. 7 and 8).—In addition to two ordinary chambers, this apparatus is provided with two auxiliary compartments, *b*, *b'*, which communicate above with the two chambers, *a* and *a'*, and below through *h* with the spaces comprised between the suction and delivery valves.

The principal chambers, *a a'*, are prolonged beneath the orifice of the suction tube so as to form a pocket of water separated by a partition, *s*, from the valve box. During the operation of the apparatus, a certain quantity of water is retained in this pocket, and this permits of having at *x* a quantity of water at the highest temperature possible.

Reid's Pulsometer (Fig. 9).—The improvement introduced into pulsometers by Mr. J. Reid concerns the construction and the action of the steam distributer, as well as the use of a condensing jet. The distributer is of the disk type. It balances upon two seats and is fixed upon a rod that carries two pistons, *f f'*, one on each side of the distributer. The rod of the latter traverses the cylinder, forming a slide valve box, and is connected with a lever which is acted upon to set the pulsometer in operation. This distributer is set in action by the steam itself. To this effect, the pistons are provided with a groove upon their circumference, and small apertures are formed in the side of the cylinder. In each of the extreme positions of the distributer, one or the other of these orifices communicates with the groove of the corresponding piston, and with small apertures in the latter leading to the back of it. So, then, when the distributer occupies one of its extreme positions, the steam accumulates behind one of the pistons and afterward repels it. In the meantime, an analogous action is preparing on the other side. A regulating valve is arranged on the tubes, *g*.

The condensing jet reaches one chamber from the other through a tube arranged at the lower part.—*Revue Industrielle.*

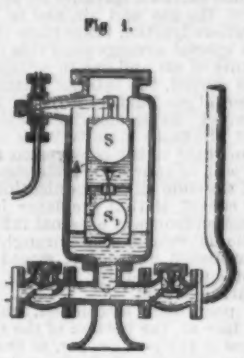


Fig. 1.

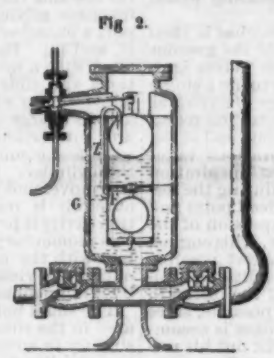


Fig. 2.

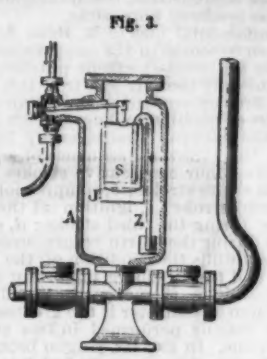


Fig. 3.

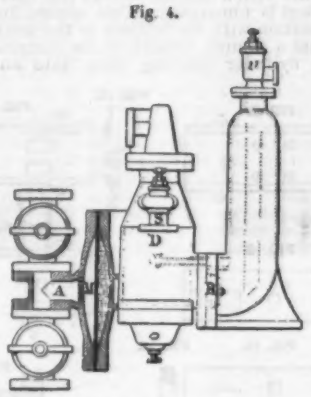


Fig. 4.

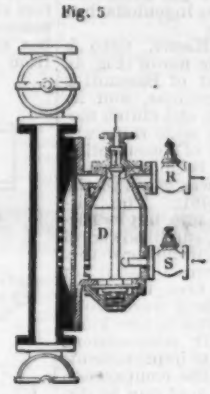


Fig. 5.

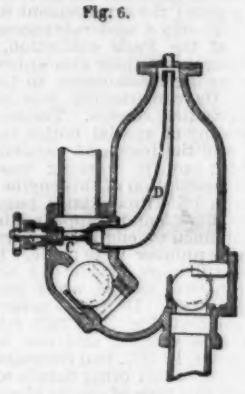


Fig. 6.

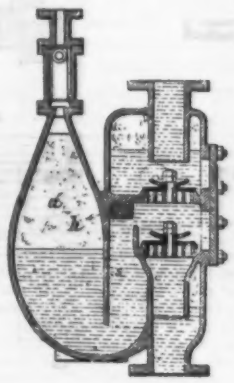


Fig. 7.

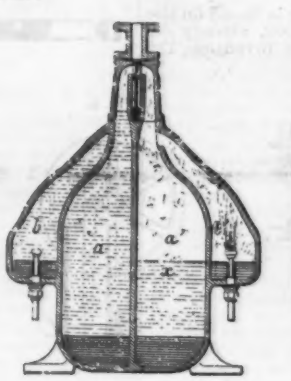


Fig. 8.

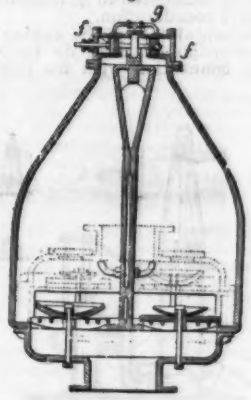
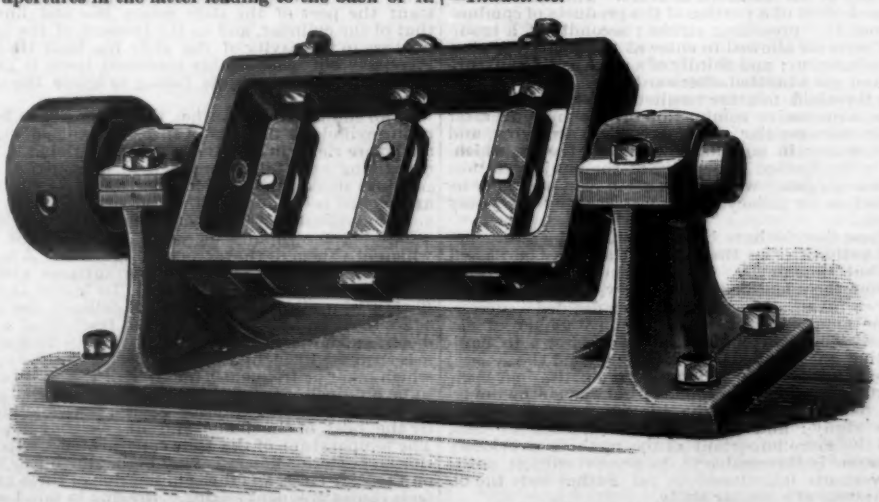


Fig. 9.

WIRE STRAIGHTENING MACHINE.

We give below an illustration of a new form of wire straightening machine, which has just been brought out by Mr. John Jardine, of Nottingham. Hitherto it has been the practice to pass the wire through solid dies. It was found, however, that the dies rapidly wore to a sharp edge and cut the wire as it passed through, leaving a mark upon it, like that in screw cutting. Mr. Jardine has therefore substituted the hardened steel pulleys shown in the illustration in the place of the dies. These pulleys do their work in as efficient a manner as the dies, while they do not possess any of the above mentioned disadvantages. The machine here illustrated occupies a space 11 in. broad by 28 in. long, and weighs 1 cwt. 2 qr. 24 lb.; it is suitable for straightening wire whose diameter is 3/8 in. or less. —*Industries.*



WIRE STRAIGHTENING MACHINE.

ARMOR PLATE.*

IN the second series of experiments (Figs. 18 to 26), the Creusot plate was the only one capable of supporting the four ten inch shots fixed by the programme. Its two rivals were so shattered that it was impossible to finish the test and fire the third shot. After the shock of the first projectile, the Cammell plate (Fig. 20) was in a worse state than the French one after the fourth shot (Fig. 25), and the Brown plate (Fig. 19) was still inferior to the other English plate.

In face of these results, and those gained from testing the specimen plates of the Italia, and which had researches had gone too far in the way of hard steels. At the beginning of the manufacture of the Terrible's plates it had used a very hard steel, and as sufficient experience had not yet been had with this quality of metal, it happened that the works, as well as the representative of the navy, allowed to be shipped to Brest three plates containing cracks. The cracks appeared at Brest at the base of the bolts, although they were not detected at the works. Creusot then took a step backward in the hardness of its steel, and simply replaced the plates that exhibited the cracks, although these had been accepted. Since that epoch, no port has ever been able to assert that it has received cracked plates. In reality there was here but a simple accident in the manufacture, which is easily avoided. Nevertheless, as was their right, the manufacturers of compound metal made a handle of it, and, since that far-off epoch, every time they present themselves to foreign countries, they take care on the one hand to praise the qualities of their product, and, on the other, to bring up the subject of the cracks in the plates of the Terrible.

On the part of the English manufacturers, this process is legitimate. They solicit orders, and use every means to obtain them, but what is not understood is the desperate efforts of French manufacturers to aid foreign competition in such affairs. Our producers of compound metal never have had any orders outside of France, and they have never taken any part in an international competition. It is Creusot alone that carries the national banner therein against Messrs. Cammell and Brown, so that in a struggle with the French works, the fighting is in definitive for foreigners and against the national industry. Fortunately, this sort of a contest has had no influence. As above stated, after the experiments at Spezia, the Italians not only ordered the armor plate of the Lepanto from Creusot, but also decided to transfer the manufacture of Schneider steel armor plate to their works at Terni. Moreover, after a long and careful inquiry made in Europe, by an official commission, the United States government decided under date of June 1, 1887, to order 6,800 tons of steel plates for its navy, absolutely excluding the compound plates. Since then other orders

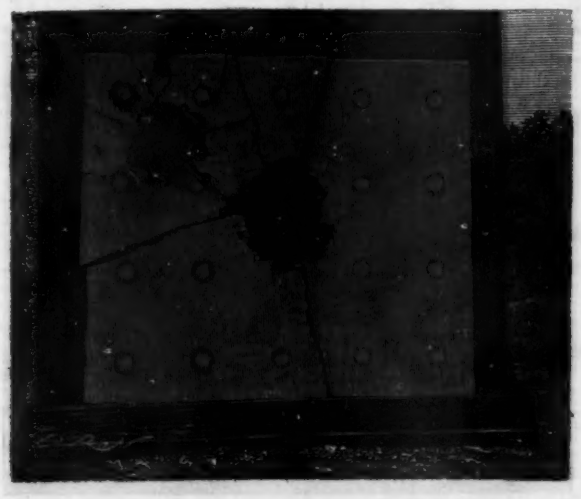


FIG. 18.—CREUSOT PLATE—FRONT VIEW AFTER THE FIRST SHOT OF A 10 INCH GUN.

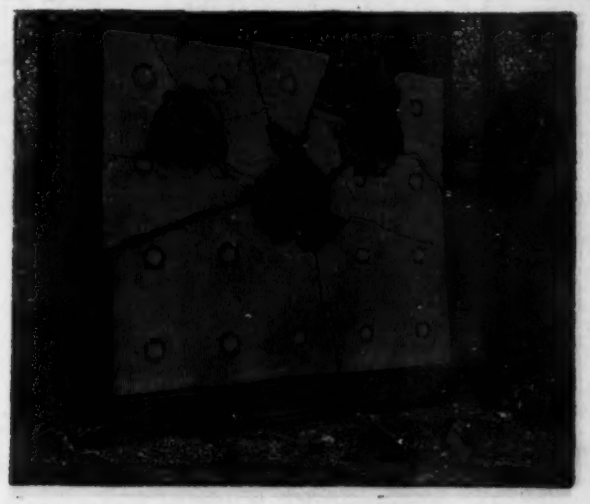


FIG. 21.—CREUSOT PLATE, AFTER THE SECOND SHOT.

FIG. 19.—BROWN PLATE—FRONT VIEW AFTER THE FIRST SHOT OF A 10 INCH GUN.

FIG. 22.—BROWN PLATE, AFTER THE SECOND SHOT.

FIG. 20.—CAMMELL PLATE—FRONT VIEW AFTER THE FIRST SHOT OF A 10 INCH GUN.

FIG. 23.—CAMMELL PLATE, AFTER THE SECOND SHOT.

not been very satisfactory, the Italian navy dropped the contract prepared with the Sheffield works and confided the manufacture of the armor plate to Creusot. Moreover, it decided that compound plates should be radically excluded from Italian naval construction, and that it would make exclusive use of the Schneider steel plates. The Terni works were then installed for the manufacture of plates of the Schneider system, according to the processes employed at Creusot. . . .

Shortly after these experiments at Spezia, an incident occurred that the manufacturers of mixed metal tried to exploit.

Urged by the navy to still further increase the resistance of its plates to penetration, Creusot in its have further increased the tonnage. Finally, the government requested the Bethlehem works, with which it had bargained for the furnishing of these plates, to secure the co-operation of Creusot in the construction of its machines, the installation of the manufacture, and the execution of about 10,000 tons of armor plates.

At the same time, confidence was becoming more and more shaky on the other side of the Channel in regard to the efficiency of the compound metal. An order for 6 inch chrome steel projectiles had been addressed to the Unieux works in France, and the results of the firing had been so brilliant that envy was this time disarmed. Certain scientific journals were not even able to withhold their admiration, and expressed themselves on the subject of these projectiles

* Concluded from SUPPLEMENT, No. 714, p. 11407.

with the ascents of lyric poets. Justice was finally rendered to our products, and it was acknowledged that we were passed masters in the manufacture of military steel. From thence to undertake a campaign against compound steel and in favor of steel armor there was but a step.

At the beginning of 1888, the Admiralty invited its metallurgists to a competition with armor of all makes. It was therefore in doubt about the compound metal, since it admitted that it was expedient to test it anew and comparatively. Several works came forward, some with the compound metal and others with steel plates. The result of the firing has remained a secret, the Admiralty having forbidden the manufacturers to be present at the tests of their competitors' products; but it appears from a note published by the maritime journals that the Vickers works presented a steel plate that behaved as well as the best among the compound ones.

It is well known that desperate efforts are making in England to produce armor steel of good quality. The results obtained are probably not yet satisfactory; but when this object has been attained, it will be loudly announced, and compound metal will be pitched overboard. At present, our neighbors are covering their retreat in good form, without saying so, for fear of losing an order.

In France, the navy always holds an even balance between compound metal and Schneider steel. It is certain that the manufacturers who have the plant for making plates of the first of these metals would have a right to complain if the administration did not take into account the expenses that they have incurred at its instigation. However, it is probable that they will not always be listened to, for it is now some years ago that the commission on *materiel* made an attempt at Guerigny to work armor plate on a large scale. It necessitated the intervention of the referee of the budget committee to cut this scheme short. We know not whether it was desired to make compound metal or pure steel; but what we can assert is that it was one of the two, not, it was said, to dispense with the concurrence of manufacturers, but solely to have a regulator of prices. It would have taken many years for the state works to earn the capital of its new equipment; and if, during this time, the science of metallurgy, making a step in advance, had discovered new processes and new alloys, the state would have been forced to follow it in its transformations and to incessantly renew its machinery.

But while the navy is taking the part of both, and sometimes, even, in a somewhat strange manner, the artillery, on the contrary, requires plates of pure steel for the tests of its projectiles.

There is another point that merits much attention. Compound metal does as well as steel for the 4 to 5 inch plates that are designed to protect the sides of the armorclads and of the armorclad cruisers in course of construction. As well known, the introduction of high explosives, such as melinite, dynamite, etc., was followed by a return toward total armoring. The Dupuy-de-Lome, of 6,300 tons, constructing at Brest, is armor-plated in her upper works, as were the Gloire and the first types of armorclads

It is certainly not without some regrets that such a determination was made, as the consequence is an increase of weight and of the cost of ships of war; but the experiments made upon the Belliqueuse at Toulon demonstrated that life would be impossible on board were the *personnel* not protected by plating and an endeavor were not made to bring about an external explosion of the new projectiles. We borrow, from an account published by an officer, a description of the ravages caused in the Belliqueuse by high explosives.

The firing upon the Belliqueuse, says he, was done with 5½ inch and 6 inch guns of the model of 1881, throwing ordinary cast iron shells of about 66 and 100 lb., containing respectively but 6 and 8¾ lb. of melinite. The following were the results obtained: The bursting oftenest occurred after the passage, and sometimes in the ship's side. The 150 and 600 grain fragments, the number of which reached about 1,500, and which had an enormous velocity, were projected in every direction, and even backward, destroying all the unprotected *personnel*. The rest of the projectile was reduced to metallic powder that penetrated the surrounding obstacles.

To these effects are added those of the explosion, which is local, but which has great energy. If it occurs while the projectile is traversing the ship's side, it makes holes therein 5 feet in diameter. When it occurs near the decks, it staves them in, breaks the beams, and even acts upon the bulkheads. It may, moreover, start fires, as occurred three times out of twelve shots on board the Belliqueuse. Finally, the movements occasioned in the atmosphere have such a force that they disorganize the slightly resistant installations of the vessel at great distances.

The Belliqueuse, which was so finely treated, was an old armored wooden corvette that had been condemned for some years, but her sides offered as much resistance as do those of most of our armorclads and all our cruisers. So the result of these experiments caused a very legitimate excitement in our navy, and in the circle of officers it was said: "We must protect ourselves at any price, cost what it may." It was in order to satisfy this desire that the Dupuy-de-Lome was put upon the stocks, the two unprotected cruisers, the contract for which was about being signed, being judiciously abandoned in 1887.

FIG. 24.—CREUSOT PLATE, AFTER THE THIRD SHOT.

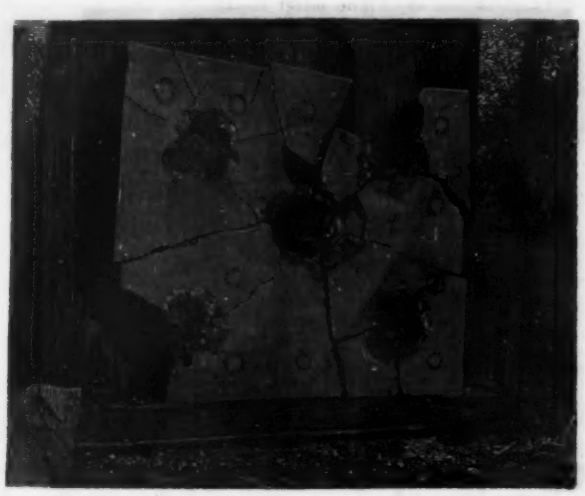


FIG. 25.—CREUSOT PLATE, AFTER THE FOURTH SHOT.

During the early months of the present year, experiments in firing with high explosives were made in England with the armorclad Resistance. Nothing, or almost nothing, has been heard about these, but, as it has been judged indispensable to invest the sides of the monster 14,000 ton armorclads that are to be put upon the stocks with 5 inch plate above their load line belt, is it not evident that these experiments were as terrifying as those with the Belliqueuse? Consequently, it should be asked, What metal is adapted for the platings of slight thickness that we oppose to the new shells?

The experiments, as a whole, do not as yet permit of forming precise conclusions; it seems to be shown by those that took place recently at Gavre that the compound metal is ill adapted for such use. On attacking 4 and 5 inch plates with a 6 inch gun and hard iron projectiles, it is found that the latter no longer break before such obstacles, but that they break the steel covering of the compound, reach the region of the iron and its backing, and spread destruction upon their route.

This phenomenon can be explained as follows: The compound plate is not homogeneous; when a projectile traverses it, it meets other different layers, to wit, (1) the hard steel covering, (2) an alloy of iron and steel, and (3) a layer of iron. As the covering is of hard steel, harder even than the "all-steel" plate, it will more easily break certain projectiles, but, as soon as it is destroyed or penetrated, it no longer offers a total medium of resistance sufficient to prevent the projectile from reaching the backing and causing great ravages in it.

In compound metal the resistance diminishes by reason of the elements that compose it; homogeneous steel, on the contrary, always presents an equal resistance to penetration. This is the explanation that is given of the fact that a 5 inch compound plate recently tested at Gavre, on the same day that a steel plate of the same thickness was, did not fulfill the required conditions as well as its rival did. It was received with the mention "mediocre," the projectile having penetrated to the backing. With a few yards more velocity it went clean through, and the plate was refused. In the steel plate the point of the projectile scarcely reached the back surface of the metal.

It is evident that we can affirm nothing so long as we shall not have brought together a number of experiments, but it is also evident that there are many chances that results will confirm the justness of the estimations that precede. It is, in fact, to be presumed that, in compound plates of slight thickness, a phenomenon occurs identical with that which must occur when compound plates of great thickness are attacked by chrome steel projectiles. The latter do not break, as a usual thing, and preserve enough live force to attack iron or mixed metal with great energy and destroy the backing.

Moreover, this question of the selection of the best armor plate deserves to be examined exhaustively. We know that the artillery service is now seeking what is called a retarding fusee, in order to permit the projectile to penetrate the plating and to explode only after penetration. The results of the experiments that have been going on for some time are kept secret, and this is well, but, if we suppose the problem solved, the end to be pursued is a search for plates of the least penetration. The interest of the ship requires, more than ever, the best armor plate; and does not the experiment mentioned above permit of doubting the future of compound metal, even for the plating of the sides of cruisers, that is to say, for armor plates of slight thickness? And if we recall the fact that this metal, when very thick, does not lend itself to the curved forms of the stem and stern, are we not right in saying that its use in naval construction is limited? A few years ago the example of the English was cited in objection to the observation that precedes, and which we then presented under another form; but it is to be remarked that, since the invention of the compound metal, the English have given up armor belts surrounding the entire load line, and have reserved this system of plating for a limited portion of the length, that is, for the

FIG. 26.—EXPERIMENTS IN FIRING, MADE AT SPEZIA IN 1884—GENERAL VIEW OF THE 19 INCH CREUSOT, BROWN, AND CAMMELL PLATES AT THE END OF THE EXPERIMENTS.

monster armorclads that they are going to put upon the stocks. The objection has no bearing then, since the English navy has no need of curved plates.

But, as a fact curious to relate, never in the memory of the engineer has the question of armorclads been more warmly discussed than this year at the meeting of the Institution of Naval Architects. Every type was examined, every idea developed, from total armor plating to no plating, but not a word was said about the plates themselves. Yet the experiments that are making on the other side of the Channel prove that this question is seriously occupying the Admiralty and the metallurgists.

In conclusion, we repeat that we believe the future of compound metal is very limited, while it may be asserted that steel has not had its last say. The latter lends itself to combinations that are impossible to the former. It is a simple metal, the treatment of which is essentially prefectible. Compound metal, on the contrary, is complex, and the treatment that the steel surface might admit of cannot be applied to the iron that forms its internal portion.

In recent years, we have manufactured excellent chrome steels in France, and we have produced chilled steel plates, which, with slight thicknesses, have shown extraordinary resistance.

Is it temerary to believe that we shall succeed in making thick plates, having the qualities of the new steels, for projectiles? The future is for the material that can be modified, and not for that which appears to have passed through its cycle. But progress in these sorts of works is not made in a day—it is the resultant of great efforts, of patient researches, and of numerous experiments. And when it is a question of plates twenty inches in thickness, of simple or compound metal, science, time, and money are great factors. Before presenting specimens of a more perfect manufacture to mariners, the metallurgist must be sure of success, and he can be so only when he has collected a number of convincing and unassailable facts.

The studies and experiments that are going on at Creusot allow us to hope that we shall succeed in producing armor platings which, with the thickness now employed, will break chrome steel projectiles. This will then be the revenge of the defense against the attack, and a simple phase of the great strife between the gun and armor plate.

It remains to mention a few examples. For the armor plate designed for the French fleet, we shall select that of the first class armorclad the Formidable, since it is the last large ship that entered into service. On the 30th of January, 1886, a diminution plate of 14-6⅞ inches thickness and weighing 57,575 lb., was tested at Gavre. It was attacked with a 10 inch gun and a hard iron ogival projectile weighing 473 lb. According to rule, three shots were fired at the apices of an equilateral triangle inscribed in the center of the plate. After this test, the Formidable's armor was received with the mention of "satisfactory;" but, in order to understand what this means, it must be known that the Gavre notation follows the following progression: "very mediocre," "mediocre," "passable," "pretty satisfactory," "satisfactory," and "very satisfactory."

We now come to the last official firing at the products of the Creusot works. On the 23d of last October, an armor plate of the corvette Gota, of the Swedish navy, was tested. The experiment was made at distant from the target. The following are the results (Figs. 27 to 31):

No. of shots.	Penetration in inches.	Observations.
1	3.8	No fissure. Ball broke and fell in front of the plate.
2	3.4	A slight fissure started from the impact of the second blow, traversed the first and ran to the right corner of the plate. The ball broke and the ogive remained implanted in the point of impact.
3	3.6	A second and very fine fissure started from the point of impact and joined the first blow. The fissure made by the second shot slightly widened and traversed the right corner. The broken ball fell in front of the plate. That of the second shot was detached under the effect of the third. The ogives were slightly distorted.

The plate had resisted admirably. A single fissure

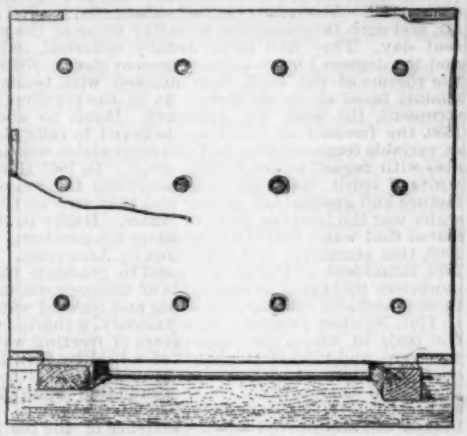


FIG. 31.—REAR VIEW AT THE END OF THE EXPERIMENTS.

started from the point of impact of the first shot and ran toward the right edge of the plate.

Before finishing, we think it will be of interest to give a statement of the quantity of armor plate steel that has been or is to be delivered by the Creusot works. On the 1st of May last, the French or foreign navies had received or ordered from this great establishment a total of 27,166 tons of armor plate; 11,543 for France and 15,623 for foreign countries.—*Le Genie Civil.*

MILITARY VELOCIPEDE IN FRANCE.

THE Minister of War has just officially sanctioned the employment of the velocipede in the French army for conveying dispatches. Each infantry regiment of the active army is to contain four velocipedists. The chiefs of the corps themselves to choose these velocipedists among the men of all grades in the reserve and the territorial army who volunteer and offer the best guarantee for fulfilling the service. The velocipedists

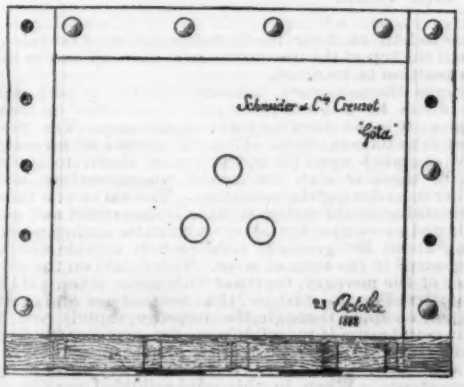


FIG. 27.—FRONT VIEW OF A PLATE OF THE CORVETTE GOTA BEFORE IT WAS FIRED AT.

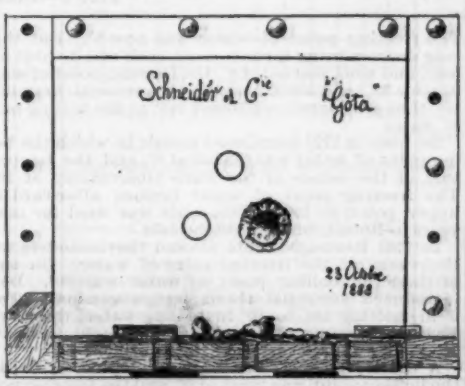


FIG. 28.—FRONT VIEW OF THE PLATE AFTER THE FIRST SHOT WITH A 5 INCH GUN.

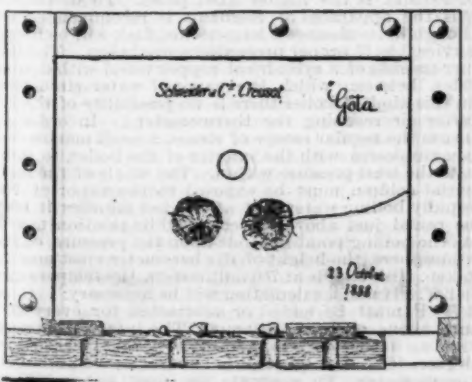


FIG. 29.—FRONT VIEW AFTER THE SECOND SHOT.

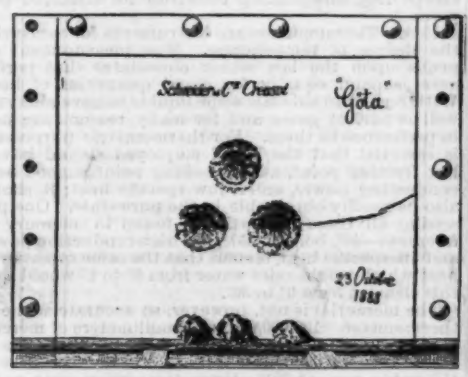


FIG. 30.—FRONT VIEW AFTER THE THIRD SHOT.

the polygon of Villedieu, a dependence of Creusot. The plate was nearly rectangular (6 × 5 ft.), was 9¾ inches in thickness, and weighed 12,650 lb.

Three shots were fired with 6 inch steel gun of 36 calibers, throwing an ogival hard iron projectile of 100 lb., with a 35 lb. charge of brown prismatic powder, with a mean velocity of 1,836 feet. The gun was 180 feet

are to provide their "mount," and keep it in good condition. In addition to the pay of their grade, they have a right to an allowance of 50 centimes per day as an entertaining premium.

The service of velocipedists on campaign or during grand maneuvers is to be arranged by the generals commanding the army corps. In fine, these general officers are equally to regulate in every detail the dress, equipment and accouterment of the velocipedists. It is to be feared that such a method of recruiting may soon become an opportunity for favor to render the time of service as pleasing as possible to certain favorites, whatever may be, moreover, their skill and vigor from the point of view of the velocipede.

The question has nevertheless been studied in France, if not as thoroughly as in England, at least, with sufficient attention for the general staff officer to form a distinct idea of the services one may expect from men, properly mounted and animated, for the transmission of orders. These are the subjects of inquiry we are about to lay before the reader.

The journal, the *Sport Velocipedique*, of Paris, official organ of the "Union Velocipedique Francaise," issued the first article on the velocipede in the army. Quite a tournament took place after it among authorities in the velocipede world. Then from articles they came to deeds. On April 22, 1886, a velocipedist of Pau, M. Daniel—the same who went from Pau to Calais, 1,100 kiloms. in 7 days 4 hours 50 min.—offered to place at the disposition of the Minister of War, for the maneuvers of the 18th corps, five or six trained velocipedists. For reasons unnecessary to mention here, it was considered preferable to have recourse to the "Union Velocipedique Francaise," which supplied eight velocipedists.

In the interval a practical attempt had been made by the Velo Club Grenoblois at the instigation of M. Terrier, one of its members. On the 15th of August, 1886, M. Brionnet carried a supposed dispatch from Grenoble to Bourg d'Oisans—752 m. in altitude—on a bicycle in a very short time. M. Dumonlard went on a bicyclette to prepare, starting from Grenoble, at Tencin and Goncelin, the revictualing the cantonment of a troop on march, that very quickly, also. In fine, in another direction and on a bicycle, M. Terrier was reported to be about to destroy the viaduct of the Moirans Railway. The three velocipedic instruments of most common use had been put into requisition according to their respective qualities. This original attempt won for its authors the praises of the Minister of War.

The maneuvers of the 18th corps in 1886 came at once in corroboration. General Cornat verified in his report that he had not employed any other estafettes, and that his messages had been carried three times as quick as before. The experiments were continued in 1887 at the maneuvers of the 19th and 17th corps, and in 1888 at those of the 3d and 16th corps, and gave equally very satisfactory results, always employing velocipedists as estafettes.

Those of the 9th corps were very well conducted, and gave rise to the following observations. The number of velocipedists who took part at these maneuvers were twenty-five—nine with bicyclettes, ten with bicycles, and six with tricycles—under the command of M. Martin, sub-lieutenant in the 71st territorial, and president of the Veloce Club of Angers. They were employed solely for the transmission of orders between staff majors and the different services. They were distributed in bands, each with a chief. The roads and paths followed in the maneuvers were generally bad; the sandy soil of the roads and the pebbles raised by the passage of the cavalry and artillery often rendered the progress of the velocipedists difficult. In spite of that, in a distance of 40 kiloms. it has been shown that a velocipedist arrived in the cantonment one hour and a half, and sometimes even two hours, before the estafette of horses, without fatigue and without being obliged to rest before setting out again; although it was often necessary to take a devious road, which increased the distance to be traveled over, but presented better ground. The speed varied from 16 to 18 kiloms. per hour, but one should count about 20 kiloms. per hour as the average speed that can be kept up during a journey.

Well trained velocipedists easily manage to ride 250 miles in a day. The following are some of the results obtained by professional velocipedists; on the machines of the Rudge Cycle Co., 34,242 meters were traveled over in one hour by M. J. Dubois on a coursing bicycle; 40 kiloms. in 1 hour and 12 min. by M. Oxborrow on a bicyclette; 10 kiloms. in 18 min. 43 sec. by M. Beconnais, of Bayonne, on a tricycle; 8,045 m. in 14 min. 8 sec. on a Rudge tricycle, special; 50 kiloms. 2 hours 4 min. 10 sec. on a tandem by Messrs. Giraud and Laval, of the "Cercle de la Pedale de Paris;" 226 kiloms. in 11 hours 50 min. 30 sec. by the same two amateurs on the same tandem; 360 kiloms. in 24 consecutive hours on a double driver by M. E. Bertaux, of Caen. But in the maneuvers and on campaign, one must take into consideration the embarrassing of roads by artillery or cavalry, who often force the slackening of the march, and even the dragging of the machine by hand. The maximum distance gone over in a day in the 9th corps was 120 kiloms. The lowest speed was 10 kiloms. per hour in a night march, on a road broken up by the passage of artillery. Colonel Saville, chief of the military velocipedy in England, says that not more than from 6 to 10 miles per hour—9,600 to 13,800 m.—should be expected from military cyclists. At the gymnastic school of Joinville, it is admitted that the average speed with a tricycle on an ordinary road and for a course of several hours is from 8 to 10 kiloms. per hour.

The machine most suitable for military purposes seems to be the tricycle or bicyclette. The bicycle, which is the lightest—average weight, 16 kilos.—cannot develop these qualifications of speed except on very even ground; its center of gravity being in the wheel in front, the contact with a stone or rut may cause serious falls forward. In spite of its brake, the stoppage can only be effected progressively. The bicyclette has more stability than the bicycle, its center of gravity being between the two wheels, on the tangent of the back wheel. Its average weight is 20 kilos. It is supplied with a brake which can stop it instantaneously, but the man stopped is obliged to descend. It is only with fatigue that a column of infantry can be followed during a certain time, at a slow pace.

The tricycle is the most stable of all, and a soldier can make use of it without any apprenticeship, as in other instances. It admits of advancing with ease at any pace, and to stop remaining seated. It has in addition this considerable advantage, that of being able to carry backward a burden varying from 10 to 20 kilos. at a maximum according to the strength of the velocipedist. Its inconvenience is that, with less speed, it occasions greater fatigue to the cyclist, on ac-

count of its weight—20 kilos. on an average—and of the rubbing of the gear, and the formation in soft ground of three ruts instead of a single one, as in the preceding models. In addition, if the cyclist is obliged to follow a column, and to traverse on one of the inclined sides of the road, he is obliged to lean in an inverse direction to his machine in an uncomfortable position for preserving his equilibrium.

An ample vareuse, giving the greatest liberty to every movement, trousers buttoning at the ankle, and laced boots, seem to be the most suitable clothes. Leggings are too hot, and laced brodequins impede the movement of the foot. It is good to add to this an India rubber tippet with a hood, to protect from the rain, and a leather bag to carry dispatches without their being crumpled. The revolver suffices as an arm for a man not intended for fighting, but only to defend himself against a chance attack. The bag can be adapted to any machine easily, but especially to the tricycle.—*La Nature.*

ELIAS LOOMIS THE PHYSICIST.

By H. C. HOVEY.

IN an inland town, a place of summer resort, an aged man, who had long dwelt apart from exciting scenes, sought new strength in order to finish his allotted work in life. But the warning came, and he bravely returned to the city where his home had been for the last thirty years, and amid the sheltering elms of New Haven he died, and amid the historic stones of Grove Street Cemetery he was buried, his bearers being Professors Dana, Newton, Brewer, Van Name, Marsh, and Wright, and his eulogist being President Dwight. The man thus honored and lamented was Prof. Elias Loomis, LL.D., who was born August 7, 1811, and who died August 15, 1889, aged 78 years. A brief sketch of his life and eminent services may be acceptable.

He fitted for college under his father, at Willington, Conn., and was graduated from Yale College in 1830. He served as tutor in that institution for three years, during which time he began the long list of brilliant scientific achievements that made his name famous on both continents. In order to qualify himself for the career before him, he spent a year or more in Paris, attending the lectures of Arago, Biot, Dulong, Poisson, etc. On his return he accepted the chair of mathematics and natural philosophy in the Western Reserve College, Ohio, which he held till the year 1844, when he was called to a similar position in the University of the City of New York. He succeeded Prof. Olmstead, in 1860, as professor of natural philosophy and astronomy in Yale University, a place which he held during the remainder of his life.

Prof. Loomis, together with Prof. A. C. Twining, of West Point, made the first concerted observations ever taken in this country of the altitudes of shooting stars, in Nov., 1834. And for fourteen months, in 1834–35, he made hourly observations every day, beginning at 5 A.M. and on till 10 P. M., to mark the declination of the magnetic needle. At a later period he took observations of the dip of the needle at over seventy stations spread over thirteen States from the Atlantic to the Mississippi. While connected with the Western Reserve College, Prof. Loomis observed 200 moon culminations for longitude, 69 culminations of Polaris for latitude, 16 occultations of stars, and determined the orbits of five comets. It should have been mentioned that he was the first person in this country to discover Halley's comet on its return to perihelion in 1835. While in the University of New York, he was interested with others in making telegraphic comparisons for longitude, determining the differences between Washington, New York, Cambridge, Philadelphia, and other localities.

Under the simple title of "Contributions to Meteorology" Prof. Loomis gave to the world through the *American Journal of Science* the results of his patient and long-continued researches in that direction. Subsequently he gave much time to the revision and systematizing of these papers, with the intention of welding them into a complete work on dynamic meteorology. It was stated some time ago that the whole number of his scientific papers would exceed two hundred. These appeared mostly as contributions to the Proceedings of the American Philosophical Society, the American Association for the Advancement of Science, *Gould's Astronomical Journal*, the *American Journal of Science*, and *Smithsonian Reports*.

But after all it may be safely said that the name of Prof. Loomis was made most widely known through his text books, which covered the whole range of mathematics as taught in college and school, and also included astronomy and natural philosophy, all of which had an aggregate circulation of more than half a million copies. Loomis' astronomy became a favorite text book in England; his calculus was translated into Chinese; and his meteorology was rendered into Arabic.

As a matter of course, Prof. Loomis was elected to membership in numerous scientific societies in this country and abroad. The University of New York conferred on him the title of Doctor of Laws. But after all his best monument remains in the hearts of the tens of thousands to whom his text books were as the gates of light, and who had a patriotic pride in the fact that he made it possible for them to master the mathematics and physics without going to any other than an American author.

A heavy affliction befell Professor Loomis a quarter of a century ago, in the loss of his cherished wife, and shortly afterward his two sons, in the natural course of affairs, went forth to their own paths of usefulness, and it followed that the great mathematician, astronomer, and meteorologist dwelt alone with his favorite sciences, and those who knew him least judged him to be a reserved and frigid man. But those who approached him on any errand worthy of consideration found him affable, attentive, helpful, and even ready to spice the graver themes of conversation with sallies of wit and humor. Professor Loomis was a man of many and varied resources. President Dwight thus summed up his character: "He was remarkably gifted by nature for the work which opened before him. His mind was penetrating and capable to hold carefully before it the relations of things, so essential to mathematical thought. He was what we conceive a fine mathematician ought to be, if the ideal is to be realized. As a lecturer he had the power of stating concisely what he had to say, and in a few well chosen words. His works bear witness to his power. He was a warm hearted and generous friend, and though he was much alone in his work and in his life, yet the element of the hermit was foreign to his character."

THERMOMETERS.*

By FRANK BROWNE.

History.—The discovery of thermometers is attributed to several philosophers of the sixteenth century. Galileo's instrument, invented before 1597, was probably the first accurate one known. This consisted of a long glass tube, one end of which was blown into a bulb, the other dipping into colored water. It was an air thermoscope and was the kind first used. Its scale was arbitrary and the readings incorrect, for the variations of atmospheric pressure had not yet been discovered. About 1611 Galileo substituted alcohol for air, and such thermometers were like those of the present day. They had large, usually spherical, bulbs, and the degrees,† intended to represent thousandths of the volume of the bulb, were marked with beads of enamel fused on to the stem. As in the previous instrument, the scale was arbitrary. Down to about 1650, the freezing of water was believed to take place at variable temperatures, and this supposition was held also with regard to the boiling point. In 1665 Hooke wrote of spirit thermometers, describing their manufacture and graduation, saying also that zero on their scales was the freezing point of water. Halley in 1693 stated that water boiled at a constant temperature. In 1702, this statement was confirmed by Amontons. In 1694, Renaldeni, of Padua, proposed to graduate thermometers by taking as standards of temperature mixtures of definite volumes of boiling and ice-cold water. In 1701, Newton proposed, anonymously, a thermometric scale in which the temperature of freezing water was zero, and that of the blood of a healthy man 12°; he found that water boiled at 34°, as indicated by a linseed oil thermometer when graduated upon this scale. In 1714, Fahrenheit substituted mercury for linseed oil, and proved the dependence of the boiling point on pressure.

Three scales have survived. The Fahrenheit is the oldest, and dates from 1724. It is used popularly in Great Britain, the British colonies, and the United States. This scale was primarily divided into 180°; zero was placed at temperate, a point corresponding with 9° C.; the point to which the alcohol rose when placed under the arm of a healthy man was marked 90°; and the temperature of a mixture of ice and salt, then believed to be the greatest possible cold, was marked —90°. In 1714 Fahrenheit again altered his scale; 0° was placed as an absolute zero, and the space between this point and that representing the warmth of the human body was divided into twenty-four degrees.

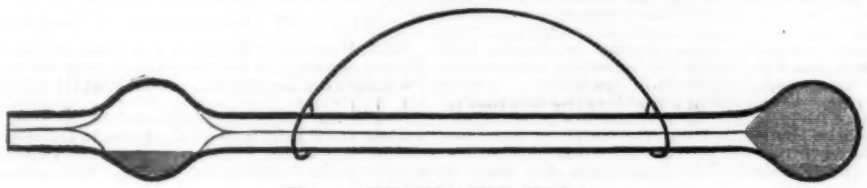


FIG. 1.—FILLING THE TUBE.

The freezing point of water was now 8°. But these long degrees being inconvenient, each was divided into four, and thus, instead of 8°, the freezing point of water became 32°, and blood heat 96°. A mercurial thermometer thus graduated registered 212° as the boiling point of water.

De Lisle in 1724 introduced a scale in which the boiling point of water was placed at 0°, and the temperature of the cellars of the Paris Observatory at 100°. The freezing point of water became afterward the upper point, as 150°. This scale was used for many years in Russia, but is now obsolete.

In 1730 Reaumur made alcohol thermometers with their zero at the freezing point of water. On some of these the boiling point of water was 80°. Delue introduced mercurial thermometers graduated from 0° in melting ice to 80° in boiling water; these, with Reaumur's name attached, are in use in Germany, Holland, and other parts of the Continent.

A centesimal scale in 1742 was adopted by Celsius; the boiling point was marked 0°, and the freezing point of water 100°. Linnæus reversed these points, and the scale is now known as the Centigrade. This is no doubt destined to supersede all others; at present it is used universally in laboratories, and generally in all except English-speaking countries for scientific purposes.

Uses.—Thermometers are instruments for measuring the degree of temperature. The measurement depends upon the law which enunciates that perfect gases expand equally for equal quantities of heat. With regard to this law some liquids behave almost as well as perfect gases, and for many reasons are used in preference to them. For thermometric purposes it is essential that the liquid employed should have a low freezing point, a high boiling point, a good heat-conducting power, and a low specific heat; it should also be readily obtainable in the pure state. One possessing all these properties is found in mercury; it freezes at—40°, boils at 357°, has high conducting power, and its specific heat is such that the same quantity of heat which would raise water from 0° to 1° would raise this element from 0° to 30°.

The mercurial is not, however, so accurate as the air thermometer. 100,000,000 cubic millimeters of mercury measured at 0° become 100,017,915 cubic millimeters at 1°; and 100,000,000 cubic mm. at 300° become 100,019,413 cubic mm. at 301°; these facts show that as the temperature increases, the expansion of mercury is not uniform. Air, on the other hand, expands twenty times as much as mercury, and equally for all temperatures. For low temperatures alcohol is most suitable, as it does not become solid till —130·5° is reached.‡ Ether is also much used. The expansions of these two liquids are 6 and 8½ times respectively that of mercury.

Manufacture.—To make an ordinary mercurial thermometer, a piece of hard glass tubing is first selected. The bore must be narrow and uniform. Its uniformity is ascertained by measuring a short column of mercury at different points of the tube. A bulb must now be blown. This varies in shape, size, and thickness according to the purpose for which the thermometer is intended. It is sometimes spherical, pear-shaped, oval, cylindrical, or tubular. Very often it is made apart from the stem; this is preferable, as one can then be chosen possessing the right capacity. When made by blowing out one end of the tube, a small elastic bottle is fixed to the open end and compressed by the fingers. For sensitiveness the elongated form is to be preferred, as in proportion to its capacity there is a much larger surface for the conduction of heat. For this reason the gridiron, spiral and bottle-shaped bulbs deserve notice. The thickness of the glass is also a matter of considerable attention, for if too thin the bulb will yield to atmospheric pressure and raise the zero point; if too thick, the instrument will be insensitive.

The tube having now a bulb at one end, a second is blown a short distance from the other end. When this latter is half cooled, the open end is dipped into pure, recently distilled mercury, which gradually rises into the tube. By judicious cooling and heating the lower bulb is gradually filled. Held by a wire handle (Fig. 1), the tube is heated over a furnace until all air has been expelled by the boiling mercury. This being done, and while the mercury is still boiling, the open end of the tube, which must not be too hot, is placed against a piece of sealing wax, some of which drawn in effectually prevents the ingress of air. When quite cool the mercury perfectly fills the lower bulb and tube. The tube is now inclined and the lower bulb raised to a temperature higher than the thermometer is intended to indicate. Some of the mercury is thus expelled. As the column begins to retreat on cooling, the tube is hermetically sealed just below the upper bulb, which is drawn off. The instrument is now stored for some time, or heated for several days to 50° or 100° above the temperature it is intended to indicate. The reason for this will shortly be seen.

Two fixed points must now be taken. The lower is usually taken first. The thermometer is placed vertically in finely pounded melting ice, or preferably snow if it can be obtained, contained in a vessel which will allow the water to drain away. When ice is used, it should be washed with water, for when it has the appearance of salt, it may be considerably lower than 0°. F. D. Brown finds that ice and water is better than ice only; also that the water used should be distilled, as when such is not the case, a temperature lower than 0° results.* The whole of the mercurial column should be immersed in the mixture. After from twenty minutes to half an hour the thermometer may be raised until the top of the mercury is seen just sufficiently for its position to be noted.

Some thermometers intended for use in very cold countries have a still lower point determined on their scales; it is the freezing point of mercury. The process is as follows: From 17 to 20 pounds of mercury are operated upon; it is first cooled down to about —10°, together with the vessels, thermometers, and ether used during the operation. The valve of a tube containing liquid carbon dioxide is unscrewed and gas allowed to escape for about a minute, during which time about 550 grains of solid carbon dioxide will be deposited in the form of snow. This is laid on the surface of the mercury, together with some ether. Having stirred up the mixture, the liberated gas and ether vapor, escaping through the mercury, rapidly cool it down and cause it to solidify on the surface, which is then stirred in. About 6 charges of acid snow and 6 oz. of ether are required to convert the mercury into a pasty consistence. When in this semi-solidified condition, the thermometers and standard are plunged in, and when the mercuric column begins to rise above the lowest point reached, comparison is made.†

The temperature of water boiling under a pressure of 760 mm. is the higher fixed point. To determine this the apparatus of Regnault is recommended, although in its absence a long-necked flask will be found serviceable, if proper precautions are taken. The former consists of a cylindrical copper vessel with double sides, between which the vapor of water circulates. In this kind of boiler there is no possibility of the exterior air reaching the thermometer.‡ In order to insure the regular escape of steam, a small manometer communicates with the interior of the boiler, to indicate the least pressure within. The whole of the mercurial column must be exposed to the vapor of the rapidly boiling water, but after a few minutes it may be raised just above the cork and its position noted. As the boiling point depends upon the pressure of the atmosphere, the height of the barometer must now be taken. If it stands at 760 millimeters, the temperature is 100°. If not, a calculation will be necessary; 1° C. or 1·71° F. must be added or subtracted for every 26·7 mm. above or below 760 mm. The interval between the two fixed points is then divided into 100 parts or degrees for a Centigrade, or 212 parts for a Fahrenheit thermometer. To graduate the scale above 100°, a column of mercury is measured below that point, then made to pass above step by step; the portions of the tube filled by the column are then divided into the number of degrees which it represents. Craft recommends that graduation above 100° be effected by means of pure liquids, as naphthalene or benzophenone,

* Read before the Chemists' Assistants' Association.—*Pharm. Jour.*

† Except where the meaning is otherwise obvious, degrees Centigrade are intended.

‡ *Phil. Mag.*, 1885, 75.

* *Phil. Mag.*, vol. xiv., p. 57.

† *Phil. Mag.*, 1886, p. 27.

‡ A figure of this apparatus will be found in the manuals of Ganot and Deschanel.

whose boiling points, 218° and 306° respectively, under a pressure of 760 mm., he considers should be taken as fixed points. When these compounds are used, an apparatus similar to Regnault's should be employed.*

Errors.—There are several causes of error to which thermometers are liable; the greatest is due to the rise of the zero point. A thermometer tube having been filled with mercury, without further preparation the zero point is taken; if it be now put aside for several months, and this point be then again taken, it is seen to be considerably higher. This fact will be noticed sometimes even after intervals of many years, although the rise usually attains its maximum after one year; its extent varies from 0·5 to 3°. This phenomenon has its fundamental cause in the imperfect elasticity of the glass. A perfect solid when heated expands, and in cooling returns to its original form, its contraction being equal to its expansion. Glass when heated expands, but does not return to its former dimensions for a considerable time after it has cooled. In the course of a few months after the thermometer has been filled the bulb generally shrinks by an amount of from $\frac{1}{2000}$ to $\frac{1}{5000}$ of its bulk. It must be remembered also that there is a vacuum inside the thermometer tube, so that the amount of shrinkage is increased by atmospheric pressure. Dr. Lowenberg supposes that after having been heated, the particles of glass are in a state of tension produced by the slight conductibility of glass, which occasions a cooling or setting in successive layers, and he thinks that this abnormal tension may disappear in consequence of oft-repeated molecular movements. Legrand holds the same view.

That the bulb is elastic and yields to pressure has been shown by Mills and Egen.† They find that the expansion of the mercury produced by a pressure of two atmospheres is twice as much as that caused by one; or, expressed as a law, the expansion experienced is inversely as the pressure. They observe also that a cylindrical is twice as rigid as a spherical bulb. The effect of the elasticity of the bulb may readily be comprehended from the results of some of Pickering's investigations. He shows that the bulb of every thermometer has two different shapes, one when the column is rising, the other when it is falling. He takes this view from some experiments in which he found that there was a considerable difference in the rate of heating and cooling, up to and down from certain temperatures. He further strengthens his supposition by calling into notice the fact that when the column of mercury rises to any temperature, it will go on rising regularly afterward; but when it falls to that temperature, a certain time elapses before it will begin to rise again, and although the mercury is expanding, the column is stationary, and therefore the bulb must be expanding and assuming a new form.‡

(1) *Rising of the Zero Point.*—If a thermometer be graduated soon after manufacture, the zero point after a short time rises and is incorrect. The graduation must, therefore, be deferred for a considerable time until no further rise takes place. As it may not be convenient to store the tubes, another method is fortunately at hand by which the period is greatly shortened. The thermometer is made and heated to a high temperature; at the end of a few days the zero rises to its utmost extent. The freezing point now taken remains afterward nearly constant. At the Kew Observatory of the Royal Society new thermometers are always subjected to an annealing process, by heating the bulbs in a sand bath for three or four days. Hicks exposes the thermometer tubes for sixteen days to a temperature of 50° or 100° above the highest point which the thermometers are intended to indicate. They are placed in linseed oil; this is gradually heated to the required temperature, and having remained at that point for the proper time, it is very slowly allowed to cool.

Mercury or any liquid which does not act upon the glass may be used. By either of these methods a rise of 2° to 2·5° has been effected in sixteen days, which would have taken months, and probably years, to effect if the annealing process had not been used. It may be said that this error, caused by the rise of the zero point, is very nearly in the inverse proportion of the expansion of the liquid contained in the bulb.§ Mercury in this particular is not the best liquid for thermometers; alcohol has been said to expand six times as much, and ether eight and a half times; therefore the uncertainty of error in the case of alcohol is $\frac{1}{6}$, and of ether $\frac{1}{8\frac{1}{2}}$, when the possible error in a mercurial thermometer is represented by $\frac{1}{1}$.

(2) *Depression of the Zero Point.*—If a thermometer in which the bulb has contracted to its maximum extent be suddenly exposed to boiling water for a short time, the freezing point is found to be lowered by 0·1° or 0·2°; this is known as the "depressed freezing point." A satisfactory explanation of this phenomenon does not appear yet to have been given by any observer. On account of this depression it is customary to ascertain the freezing before the boiling point; the reverse should be done if the instrument is intended for high temperatures, otherwise the readings taken will be 0·1° or 0·2° below.

(3) *Error of Parallax.*—An apparent change in the situation of the end of the mercurial column, owing to the eye not being in the same horizontal plane as the mercury. If the eye is too high, too high a temperature is taken; if too low, the temperature recorded is too low. When looking obliquely at the top of the mercurial column, the graduation mark at that point is reflected from the outside of the mercury. This cannot be seen when the eye is level with it, consequently this fact may be applied for overcoming the difficulty. Another method is to take the reading through a narrow slit in a sheet of note paper or by using a cathetometer.

Minor sources of error are, expansion of the glass, unequal expansion of the mercury, reading the thermometer placed in a vertical position (this is an error only under certain conditions), volatilization of the thermometric liquid, and inertia of the bulb. Although the expansion of the glass gives rise to an error above 204·5°, it does not do so below that temperature, for in the latter case it almost exactly compensates for the unequal expansion of the mercury. Comparing the air thermometer with the mercurial, the following figures show the compensation:

Temperature indicated by air thermometer.	By mercurial.*
200°	200°
300°	300°
350°	354°

When a thermometer that has been graduated in a horizontal position, which is seldom the case, is read in a vertical position, an error of from —0·1° to —0·2° is occasioned, owing to the column of mercury pressing upon and dilating the bulb.

Volatilization of the mercury takes place at all temperatures; but at about 150° an error is very liable to be caused, particularly if the upper portion of the tube is comparatively cool. In Geissler's instruments a small volume of hydrogen is contained in the tube, which considerably retards the volatilization.

The inertia of the bulb causes the mercury to rise by a series of small oscillations; in instruments of fine bore about a dozen taps should be given before reading, while less delicate ones require tapping for two or three minutes.†

It is sometimes noticed that the mercury refuses to pass certain points of the tube; this Pickering attributes to a difference in the nature of the glass. Instruments intended for delicate work should be examined for any such imperfections.

When taking exact readings, the whole of the mercury column should be immersed in the liquid. When this is not done, an error arises, owing to a portion of the column not being exposed to the same temperature as the bulb. An approximate correction of this error may, however, be made as follows:

Ascertain the mean temperature (t) of the air or other medium to which the upper portion of the stem is exposed, by means of a second thermometer, the bulb of which is placed in contact with the stem of the thermometer used in the determination. Then if (a) represents the number of degrees of mercury not immersed in the liquid, and (T) the thermometer reading, to this latter must be added 0·00016 : a (T—t). 0·00016 is the difference between the coefficients of cubical expansion of mercury and glass, or the apparent coefficient of expansion of mercury in glass. In long and massive thermometers 0·00012 may be written for 0·00016, and the air temperature may be taken for (t).‡

Verification and Calibration.—It has been shown that many errors may occur in thermometers; in accurate work it is essential to ascertain to what extent these exist, in order that the proper corrections may be made. This is effected by several methods; the most frequently employed are:

1. Verification by comparing with a standard.
2. Bessel's method, simplified by Professor Forbes.§

I. Verification.—In this method the thermometer is compared with a standard, which is usually a mercurial thermometer. The standard and the thermometer to be tested are placed in a vessel of water, which is gradually heated to the required temperature, and the readings taken when the mercury in both has become stationary. The water is kept in motion by a stirrer, and the bulbs of the thermometers should be surrounded by the water. The readings are taken by a telescope with a cross wire, which is placed in front of the thermometers, and which is moved up and down by a rack and pinion. The readings are taken by the eye placed in front of the cross wire, and the thermometers are moved until the cross wire is in line with the top of the mercurial column. The readings are taken in succession, and the mean of several readings is taken. The thermometers are then placed in another bath, and the operation repeated at another temperature. The errors of the thermometer are then found by comparing its readings with those of the standard. If the thermometer has been purchased of well known apparatus makers, been regarded as correct, serious errors might have arisen.

Table showing temperature indicated by the six thermometers and a Standard S. when similarly exposed to heat.

s.	a.	b.	d.	e.	f.	h.
°	°	°	°	°	°	°
0	0·5	1	1	1·5	1	0·75
5	5·5	6	6	6·25	6	5·75
10	10·5	11	11	11·25	10·75	10·75
15	15·25	16	16	16·25	16	16
20	20·35	21·1	21·1	21·35	21·1	20·85
25	25·6	26	26·1	26·35	26·2	26·1
30	30·6	31·1	31	31·35	31·35	30·6
35	35·6	36·1	36·1	36·35	36·35	35·85
40	40·5	41	41	41·25	41·25	40·75
45	45·5	46	46	46·1	46·25	45·75
50	50·5	51	51·1	51	5 ·5	50·5
55	55·5	56	56·1	56	56·5	55·25
60	60·5	61	61·1	60·75	61·5	60·5
65	65·5	66	66	65·75	66·5	65·25
70	70·5	71	71·1	70·5	71·25	70·5
75	75·5	76·5	76	75·75	76	75·25
80	80	81	81	80·5	81	80·25
85	85·1	86·1	85·85	85.35	85·6	85·35
90	90·1	91·1	90·6	90·35	90·6	90·1
95	95·1	96·1	95·1	95·1	95·1	94·85
100	99·85	101·1	100·35	100·1	100·6	100·1
105	104	105	105	105·25	105	105
110	109·4	110·4	109·65	110·4	109·9	109·9
115	114·35	115·35	114·85	115·1	114·85	114·85
120	118·8	119·8	119·55	120	119·8	119·3
125	123·8	124·8	124	125	124·8	123·8
130	128·8	129·8	129	130	129·8	128·8
135	133·75	134·75	134·25	135	134·75	133·75
140	138·7	139·2	139	140	139·7	138·7
145	143·6	144·1	143·1	144·6	144·35	143·1
150	148	149	148	149·75	148·5	148
155	152·5	154	152·75	154·75	153·25	152·75
160	157·5	158·5	157·5	160	157·75	157·5
165	161·9	163·4	162·4	165·4	162·4	162·15
170	166·8	168·3	167·8	169·3	167·2	166·8
175	171·3	173·3	173·8	174·3	172·3	172·3
180	176·3	178·3	177·8	179	177·3	176·8
185	181·25	183	182·75	183·75	182·5	181·75
190	186·2	188·2	187·2	188·2	187·3	186·8

II. Calibration.—In this method a standard is not required. In order that this method may be perfectly intelligible, the calibration of a thermometer is described in detail.

The freezing point was first determined and was found to have risen 0·1°. The apparatus used consisted of a cylindrical lamp glass, filled with powdered ice and resting upon some coarser lumps at the bottom of a large beaker; the space between the outside of the glass and the beaker was filled also with powdered ice. After the thermometer had remained in the inner vessel for twenty minutes the reading was taken by removing the ice, so that the zero might be seen without raising the scale.

The boiling point was then determined by exposing the thermometer to the vapor of boiling water contained in a long-necked flask. Steam was allowed to escape through a piece of glass tubing bent at right angles passing through the cork. The top of the mercurial column remained constant for about fifteen minutes at 100·3°; the barometer was then read, and indicated a pressure of 770·5 mm. As water boils at 100° only under a pressure of 760 mm., the true point was calculated; it has been observed that 26·7 mm. above 760 mm. raised the boiling point of water 1°, and the barometric pressure was now 10·5 mm. above 760 mm. The true boiling point is therefore at 100·3° —0·39° = 99·91°, or 0·09 under the 100° indicated on the scale.

A column of mercury had now to be detached, and the bore of the tube measured from 0° to as near 100° as possible. The length of this short column should be, if possible, an aliquot part of 100°. A little difficulty was at first experienced in obtaining a column sufficiently short. This was overcome by tapping the upper end and allowing a little mercury to run down the tube; a jerk was then given in a downward direction and another away from the operator. When a short column is separated, it may be made shorter by bringing one end of the column contiguous to the remainder of the mercury, then cooling; if it is required longer, heat must be applied. In either case a jerk must be given away from the operator immediately after the heating or cooling. In this way a column of exactly 12° was made to pass step by step from 0° to the point nearest 100°, which was 95·8° after eight columns had been measured. The calibration was then continued to 180°.

0° on the scale has been shown to be 0·1° too high; its correct reading is therefore —0·1°.

The last reading was 95·8°; assuming the error here to be the same as at 100°, the true reading is 95·8° + 0·09° = 95·89.

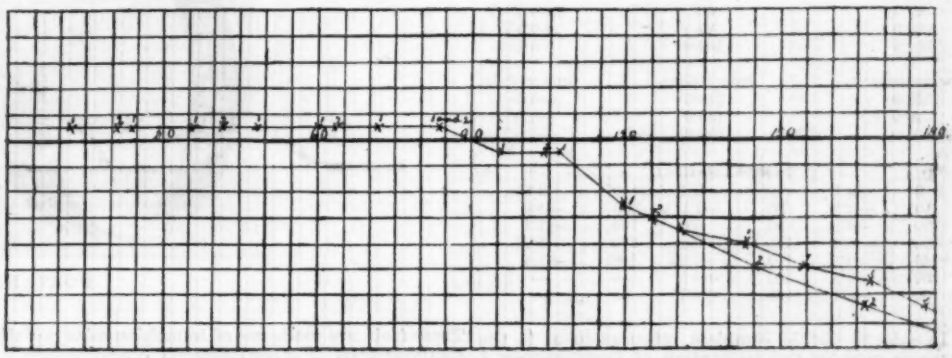


FIG. 2.—CHART SHOWING THE RESULT OF THE CALIBRATION OF A MERCURIAL THERMOMETER.

The numbers 1 and 2 opposite the crosses show where the end of the mercury column rested in the two experiments.

In the course of an investigation conducted in the Research Laboratory of the Pharmaceutical Society it became necessary to regraduate six thermometers; for these the first method was employed. As more than one instrument was verified at a time, only three similar experiments were required. The standard and thermometers were first placed in melting ice and the zero points determined. Melting ice was then exchanged for water, which was slowly heated to 5°, as indicated by the standard. The position of this point was then observed upon the other instruments. This plan of procedure was followed up to 15°, when a different apparatus was required. This consisted of a boiling tube, length about 1 meter, half filled with water. Two thermometers and the standard were fastened together by India rubber bands, and in order to overcome the effects of convection currents they were fixed by means of grooved corks in a long test tube, which was also filled with water. The thermometers were completely immersed in the liquid. Heat was now applied, and when the mercurial column reached the required point, it was kept there for a few seconds while readings were taken. The water was constantly agitated. The comparison of the boiling points having been made, the water was removed and glycerine substituted; the process then proceeded as before. The thermometers marked a, b, d, e, f, and h were verified for every 5° from 0° to 190°. In the curves the abscissæ represent the readings of the scale, and the ordinates the errors. The curve to the right of the letter in every case represents the particular thermometer denoted by that letter. From the table it is seen that the zero point of—

(a)	had risen	0·5°
(b)	"	1·0°
(d)	"	1·0°
(e)	"	1·5°
(f)	"	1·0°
(h)	"	0·75°

The errors are greatest at about 170°. In f at 27° there was an inequality in the bore of the tube, it being perceptibly constricted at that point.

It is clear that had these instruments, which had

* *American Chem. Journ.*, vol. v., No. 5.
† *Phil. Mag.*, 1887, 406.
‡ *Phil. Mag.*, 1886, 330.
§ "Encyclop. Britannica." (Heat.)

* Fownes' "Chemistry," p. 32.
† *Phil. Trans.*, 1836, 330.
‡ Kohlrausch's "Physical Measurements," p. 79.
§ *Phil. Trans.*, 1836, 573.

The value of the space from starting point to finish is readily seen to be 95·89°—the true reading at 0°, which is —0·1° (this being a minus quantity has therefore to be added)=95·99°. This space had been traversed by eight columns, therefore the value of a single column or $I = \frac{95·99}{8} = 12°$.

The readings taken at the points which the column successively reached can now be corrected. The true temperature in every case is length of the column or I — error at 0°. Thus at the first point, 12°, at which the column rested the true reading is 12°—0·1 = 11·9°, at the second 2 I—0·1, or 23·9°, and so on.

A lens was used to take every reading. The exact part of the degree at which the end of the column stood was determined by means of a degree magnified, divided into ten parts, sketched on a piece of paper, which was placed by the side of the degree in which the end fell.

The results are recorded in the tables below; they are projected also into a curve (Fig. 2), from which the error at any point of the scale can easily be seen. The accuracy of the method is seen by comparing the results obtained by using, first, a column of 12°; secondly, one of 21°. Two columns should always be taken, as they serve to fix the errors at a greater number of points on the scale. The process is not tedious, requiring only three or four hours for its accomplishment. The mean is taken of the two results.

First Experiment.

True temperature.	Scale reading.	Error of scale.
−0 1°	0°	+0·1°
11·9	12	+0·1
23·9	24	+0·1
35·9	36	+0·1
47·9	48	+0·1
59·9	60	+0·1
71·9	72	+0·1
83·9	84	+0·1
95·9	95·8	−0·1
107·9	107·8	−0·1
119·9	119·4	−0·5
131 9	131·2	−0·7
143·9	143·1	−0·8
155 9	154·9	−1·0°
167·9	166·8	−1·1
179·9	178·6	−1·3

Second Experiment.

−0·1°	0°	+0·1°
20·9	21	+0 1
41·9	42	+0·1
62·9	63	+0·1
83·9	84	+0·1
104·9	104·8	−0·1

True temperature.	Scale reading.	Error of scale.
125·9	125·3	−0 6
146·9	145·9	−1·0°
167·9	166·6	−1·3

Table of Corrections.

0°	−0·1°	70°	−0·1	140°	+0·85
10	−0·1	80	−0·1°	150	+1·0°
20	−0·1	90	0 0	160	+1·1
30	−0·1	100	+0·1	170	+1·25
40	−0·1	110	+0·15	180	+1.4
50	−0·1	120	+0·5	—	—
60	−0·1	130	+0·7	—	—

In order to obtain complete information as to the methods used for the verification of thermometers, I was enabled to watch at the Kew Observatory of the Royal Society the graduation of an instrument intended for a standard. Instead of dividing the interval between the zero and boiling points into 100 parts, without paying regard to the bore of the tube, the following process was employed:

The thermometer was attached to a dividing engine, furnished with a micrometer eyepiece having a cross wire in its focus. One end of a short detached column of mercury was placed in the focus of the micrometer, a screw was turned until the other end became visible. Thus its length was ascertained in revolutions of the screw. This process we repeated until the column had been measured for every length of itself from below 0° to 100°. The length of tube comprised between these latter two points was then ascertained. This was divided by the number of calibrations included in that portion; this gave the mean length of a calibration. The value of this in degrees was ascertained by dividing 100° by its length; the value in degrees of each calibrated portion was then obtained. The tube was then dipped into melted beeswax, contained in a long cylindrical tin, around which steam passed. Afterward it was again placed on the engine and divided by means of a fine needle point into the requisite number of degrees. These were etched upon the glass by dipping into hydrofluoric acid, and the wax having been melted off, a mixture of lampblack and oil was rubbed in to fill up the graduation marks.

In another room verification was conducted. The freezing point is ascertained by placing the thermometers in a wooden box filled with powdered ice, from which the water is allowed to drain. Above 0° to 100° verification is effected by fixing about forty instruments and a standard to a revolving stand. This is placed in a copper cylinder filled with water; there is a slit about two feet long in one side of this, glazed with a sheet of glass. Loss of heat is obviated by placing this cylinder in a wooden box, the space between the sides of the box and the cylinder being filled with sawdust. An aperture in the side of the box is cut out, opposite to the glass plate of the internal vessel. Heat is applied by a boiler which sends heated water to the top of, and receives the cooled water from the bottom of, the water vessel. A handle turns a number of paddle-wheels, which revolve in the center of the stand; thus the water is thoroughly mixed. When readings are taken the source of heat is removed, and another handle is turned, by which the thermometer frame is turned once round forward and once backward. Each instrument is read twice, and the mean of the two readings is taken.

The verification of clinical thermometers has an entire room devoted to it. The apparatus is much the same as that used for ordinary instruments, except that a separate heating arrangement is not used; fewer readings are required, usually about four. Each then has K. O. (Kew Observatory) and a number, succeeding that of the thermometer last verified, etched upon it.

Various Forms of Thermometers.—A description is given only of such of which the construction has been modified for some scientific or technical requirement.

1. *Minimum Thermometer.*—Many forms are in use. Casella's consists of an ordinary thermometer, of which the bulb is furnished with an overflow chamber; when a rise of temperature occurs, the mercury expands into this chamber, from which it cannot pass when a fall of temperature takes place. The height of the column in the stem now indicates the minimum temperature reached.

2. *Maximum Thermometer.*—A small plug of porcelain is inserted just above the bulb; the expanding mercury passes this, and when once past, can no longer return; the maximum temperature is thus easily read off.

3. *Six's Maximum and Minimum Thermometer.*—One form consists of a U tube having a bulb at each extremity. One arm of the tube is half filled with mercury; one bulb and the remaining portion of the tube above the mercury is filled completely with alcohol; the other bulb is only partially filled with this liquid. A steel index, prevented from falling by a hair tied round it, moves on the surface of the mercury in the side tubes. Should a rise of temperature take place, the spirit in the full bulb expands, causing the mercury to push up the index in the other limb. The reverse of this occurs when a diminution of temperature takes place. The lower ends of the indices nearest the mercury indicate the maximum and minimum temperatures.

4. *Solar Radiation Thermometer.*—When an electric current is passed through a vacuum, the inductive spark is white, filling the whole tube. Any pressure exceeding one tenth of an inch will not show this effect; if moisture is present, a redness in the light is perceived. These facts are made use of in making solar radiation thermometers. The thermometer is surrounded by a chamber, having a platinum wire near each end. This is made vacuous; the test is then applied and the perfectness of the exhaustion determined.

The instrument is now exposed to the sun's rays, and a true indication of their temperature is given by the height of the mercurial column. Upon the perfect exhaustion of the chamber the accuracy of the thermometer depends.

5. *Immisch's Metallic Thermometer.*—This consists of a minute tube, filled with liquid and fixed at one end; the other end bears on the short arm of a lever, the long arm of which acts by a rack on the pinion forming the axis of the pointer. They are watch shape, one inch in diameter, and very accurate.

6. *Clinical Thermometer.*—Perfection in these seems almost to have been reached. They may be obtained only two inches in length, and are sometimes fitted with lens fronts, so that their scales are magnified many times—a great desideratum considering the small size of the instrument.

7. *Fire Alarm Thermometer.*—A thermometer is balanced on a knife edge, a sliding band having previously been placed at the temperature which has not to be exceeded. So soon as this temperature is reached, the mercury overbalances the thermometer, and causes its upper end to make contact with the wires of a battery; a bell immediately rings loudly and continuously until attention has been called.

I wish to thank Mr. G. W. Whipple, B.Sc., F.R.A.S., superintendent of the Kew Observatory of the Royal Society, for allowing me to watch there the methods employed for the verification and calibration of thermometers; also Mr. Hicks, 9 Hatton Garden, for lending me the thermometers to illustrate this paper.

A PORTABLE SUN DIAL.

SOME years ago, an antiquarian made me a present of a small brass ring of a singular form, that he did not know the use of and could not tell where it came from.

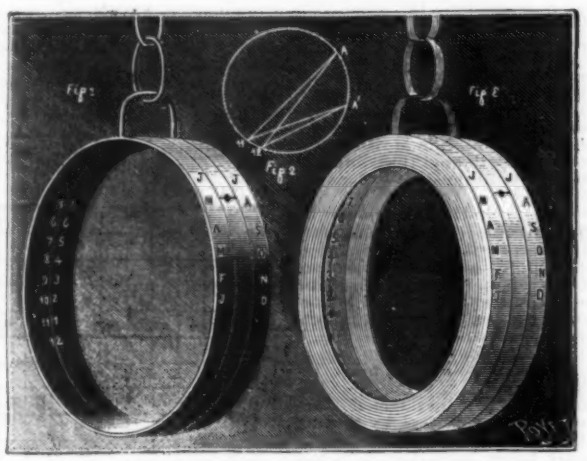
Set into a groove on the exterior of this ring (Fig. 1) there was a brass band that could be moved circularly. This band contained an aperture traversed by a straight line at right angles with its sides. Upon examining the ring more closely, I noticed upon the external part, not far from a ring that apparently served to support it vertically, some ill-formed letters, in which I recognized the initials of the names of the months, and, in the interior, a series of figures on each side of a line. The band covered a slit formed in the ring near the letters.

After turning this singular object over and over again, the idea occurred to me that it might have served as a sun dial of a peculiar kind, based upon the variation of the height of the sun above the horizon during the day. An experiment soon confirmed this. A few rough measurements showed me that this sun dial had been constructed for a latitude that I estimated to be that of London.

I have, on several occasions, had an opportunity of assuring myself that this form of sun dial is very little known. I have, however, found a trace of it in an English book entitled "Time and Time Tellers," the author of which (J. W. Benson) states that it was one of the first timepieces ever constructed. Rings of this kind were extensively used during the last century. They were manufactured in large numbers at Sheffield, when watches were still too expensive to be generally used. Some of these rings, of superior construction, were made in such a way that they could be employed in various latitudes.

The elementary theory of this instrument is easy to establish. We find that the nearer we approach the summer solstice, the more the aperture, A, is to be lowered. Outside of the equatorial zone, its extreme positions differ by about 94°. But thanks to a well known property of the circle, the angles, such as 11 A 12, 11 A' 12 (Fig. 2), having their apex in the various points that the small aperture can occupy, and the sides of which pass through the same hour figures, are equal. The instrument would therefore be perfectly accurate were the differences between the heights of the sun for two determined instants of the day the same at every season. Such is not the case; but, upon adapting the internal figures to the mean of the variation in the solar height, we succeed in reducing the extreme errors to less than a quarter of an hour for a mean latitude. It is easy to satisfy one's self, without any calculation, that this instrument cannot be employed in high latitudes, since, at the poles, the sun is perceptibly at the same height during the entire day.

It is very easy to construct a portable sun dial of Bristol board. It is well to give it a diameter wider than four inches, and to secure an invariable form by strengthening it with rings cut out as shown in Fig. 3.



PORTABLE SUN DIAL.

A plumb line placed within serves to control its verticalness.

This little device will perhaps tempt some of our readers, who will find in the construction of the instrument a good opportunity to study the apparent motion of the sun.—*C. E. Guillaume, in La Nature.*

THE AGEING OF LOGWOOD.

IN some articles on logwood by L. Bruehl in the *Textile Colorist*, a subject of importance to logwood users is touched upon, namely, the necessity for the ageing, or mastering as it is called here, of logwood.

It is well known that logwood, when freshly cut, is of a pale yellowish brown color. On exposure to the air it gradually acquires its characteristic red color, this being due to changes in the coloring principles of the wood, which exist in the wood in three forms, first as a glucoside, secondly as hœmatoxyline, a colorless body, and lastly as the color hœmateine. The glucoside which exists in the wood splits up by some change into a glucose and hœmatoxyline, and this latter body, by oxidation, is transformed into the colored body hœmateine.

This change occurs naturally, but the process is a very slow one. It can be brought about more rapidly by artificial means, and herein constitutes the process carried out by all dyewood grinders of ageing the logwood, which is done because most dyers think that the darker the wood the richer it is in coloring power, and, therefore, they demand dark wood from the dealers, who naturally supply the demand of the dyers. Now Bruehl states that this oxidized or aged logwood does not yield as fast colors as fresh wood does. After testing samples of wood oxidized in several different ways, he found the unoxidized wood to give colors superior in their power of resisting exposure to light as well as to washing and the action of chlorine.

It may then be asked why should logwood be aged if unaged logwood gives better results? Probably the reason is this, that for most of the uses to which logwood is put, it is necessary to have clear decoctions, and it is easier to get a decoction from aged than from fresh logwood, and the decoctions, too, look stronger, even if they are not really so. For some classes of goods, blacks, a decoction is by no means necessary, and the wood may be used direct in the dyebeck with much more satisfactory results than if a decoction were used; the color obtained would be more solid and fast; the wood could easily be brushed off the goods after dyeing, and, from some experience, we are of opinion that a decoction made from fresh wood would be found to give much better results than one prepared from many of the extracts which are nowadays so largely used, and the constitution of which is so very doubtful.

PROCESS OF PREVENTING THE OXIDATION OF METALS WHILE IN A HEATED CONDITION.

By GEORGE WYCKOFF CUMMINS and JAMES HENRY COLEMAN, of New Haven.

THE figure shows in sectional side elevation a view of the entire plant.

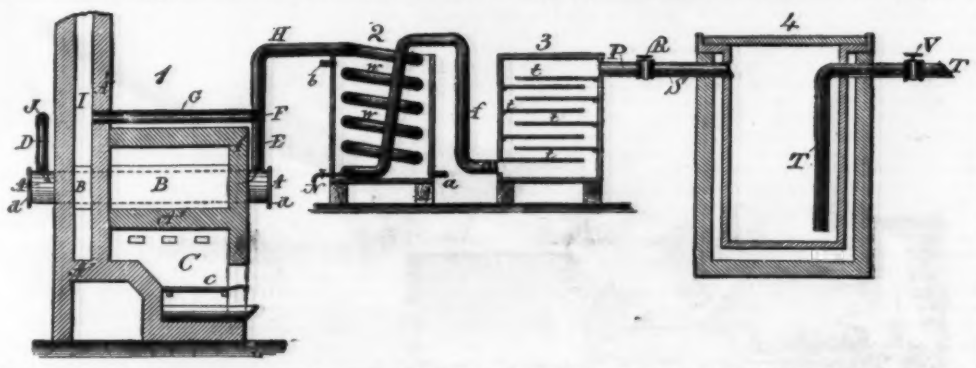
1 indicates a gas generator, 2 a cooler, 3 a desiccator, and 4 an annealing pot or chamber. The cooler and annealing pot may be cylindrical in exterior shape, if preferred, and the desiccator preferably square or rectangular.

The several parts above named may be described as follows:

The furnace or generator, 1, consists of cast iron retorts, A, two or more in number, protected by firebrick, B, set within ordinary brick work, A', such as is used for the setting of coal gas retorts. The retorts, A, are heated by a furnace or furnaces, C, provided with grates, *c*, and appropriate flues, as in furnaces for the generation of coal gas. The retorts, A, are each closed by doors, *d*, at each end and provided at one end with an inlet pipe, D, and at the other end with an outlet pipe, E, each of which outlets delivers into one common outlet pipe, H. The pipe, F, connects the two pipes, E, and from the pipe, F, the pipe, G, leads to the escape flue or chimney, I. Valves, K, L, and M, govern the flow of the gas as desired, the special office of which valves will be hereinafter more particularly described.

The cooler, 2, may be made with a worm, *w*, as shown in the drawings, for the gas to pass through, like any common "still" or condenser, any moisture condensed within said worm from the gas being drawn off through the cock, N, the cooling water entering at *a* and leaving at *b*, or *vice versa*. A gas holder of any common and well known form—such as is used for storing common illuminating gas—may be, if desired, located between the cooler, 2, and the desiccator, 3. The size of this holder will be determined by the quantity of gas desired to be stored. The smaller its size, however, the less costly the construction and materials of the holder will be.

The desiccator, 3, consists of a closed box or chamber containing trays or shelves, *t*, on which is placed fused calcium chloride. Said trays are so arranged that the gas entering at *o* must pass over a considerable surface of said chloride before emerging at P. Instead of calcium chloride, pumice stone moistened with concentrated sulphuric acid may be substituted. This substituted desiccating material has the advantage that the pumice stone does not need removal or renewal, for so long as supplied with the acid it is a rapid and thorough desiccator. The acid is readily renewed without opening the desiccator by permitting it to trickle or fall in drops on the pumice stone, through suitable pipes or orifices in the walls of the desiccator, over the pumice stone.



PROCESS OF PREVENTING THE OXIDATION OF METALS WHILE IN A HEATED CONDITION.

Of course it is understood that iron or steel, when heated to redness, readily absorbs oxygen at its surface from atmospheric air or any other source from which it can obtain oxygen, the surface of the metal thereby becoming rough and covered with scales of oxide. The endeavor, therefore, under such circumstances, in the treatment of metals is to exclude, as far as possible, from the presence of the hot metal all sources or media whence it can absorb oxygen. Even in annealing heretofore, while the annealing vessels were closed air-tight, the residual atmosphere present always exercised deleterious influence upon the metal being annealed.

This invention excludes the atmosphere and substitutes therefor an artificial atmosphere, which entirely surrounds the metal from before it is heated until it has been cooled, or through the annealing process of both heating and again cooling. The artificial atmosphere or gas used by us for this purpose may be said to be a mixture of nitrogen, carbonic oxide, and carbonic acid (N CO CO_2) entirely freed from the vapor of water. Without confining ourselves to these proportions, it may be stated that the gas may consist of about sixty-eight per cent. of nitrogen, about twenty-seven to thirty-three per cent. of carbonic oxide, and from a trace to about four per cent. of carbonic acid.

The gas, as prepared in the process below described, is non-inflammable and non-explosive, and is entirely inert as to any action upon iron or steel at any temperature, but a perfect preventive of oxidation, while the metal is excluded from the air by its presence.

The method of manufacturing the gas necessary for conducting the operation of treating the metal therewith, and the process of so treating the metal, will now be described.

When the retort, A, has been heated to incandescence by the furnace, C, the former is filled with charcoal or coke, which, as soon as it becomes sufficiently heated, evolves a gas somewhat of the nature of ordinary coal gas, but as such gas had nearly all been previously removed from the charcoal or coke in the production of the same, the evolution of such gas is of short duration. This preliminary gas product is inflammable and not at all suited to the purposes of the invention. On the contrary, it is injurious to the metal to be treated. Said gas is therefore permitted to escape through the pipes provided with valves. When the evolution of said gas ceases, a current or blast of air is introduced at J, through the pipe or pipes, D, and valve or valves from any suitable blower (not shown) and forced through the mass of incandescent charcoal or coke. This blast is permitted for a short time to escape into the atmosphere through the pipe, G, and flue or chimney, I. When all watery and hydrocarbon vapors have been thus expelled from the charcoal or coke, the gas then evolved by the blast of air may be regarded as consisting, essentially, of nitrogen, carbonic oxide, and carbonic acid, the first and last gases being considerably in excess of the carbonic oxide. This mixture of gases, though possibly retaining a trace of watery vapor, is ready and fit to be passed from the generator 1 to the cooler 2, and thence through the desiccator 3. In its passage through this latter vessel the last trace of watery vapor is removed from the gas, and it is then in suitable condition to be passed into the annealing chamber or pot, or it may be first stored in a gas holder such as above described until needed for use in the annealing process.

In the practical conduct of the operation only one of the retorts, A, need be used at the same time for the production of the blast gas. Immediately upon ceasing to use the gas from one retort and commencing to use it from the other, the charge of charcoal or coke is renewed in the first retort, and allowed to become heated until the charge in the second retort is about half exhausted by the air blast. By this time the charge in the first retort has reached the condition of freedom, more or less complete, from watery and hydrocarbon vapors previously described, and the blast of air is again passed through the first retort, when the second retort is recharged and the same round of operations continuously carried on at will.

By such mode of operation a constant production and supply of suitable blast gas is secured.

The annealing chambers, boxes, or pots are kept filled with the gas under a steady pressure while the same are both being heated and while being permitted to cool, the gas entering through pipe, S, and valve, R, and leaving through pipe, T, and valve, V. Upon the removal therefrom of the articles subjected to such gas in the annealing process, no change whatever will be observed to have been produced in bright iron due to its exposure to such gas. The air is forced through the retorts by displacement rather than exhausted therefrom, because any leakage that may occur must be outward and not inward, for if the leakage were inward the admixture of external air that would in such manner take place would change essentially and deteriorate the properties of the gas.

Even were the blast gas absolutely free from watery vapor when leaving the retorts, the interposition of the cooler is necessary, for if the blast gas were permitted, while hot to enter the cold annealing vessels and while the metal therein was surrounded with cold air, the admixture of the hot gas with such cold air would create a medium surrounding the metal that would oxidize the metal. As it is necessary to start the operation only when the annealing vessel is cold, and to keep up the blast of gas until the annealing is complete, by which time the annealing vessel has cooled down considerably, though not necessarily enough for a fresh start, the further cooling of such a vessel may be hastened somewhat, if desired, by passing the cold gas through it before starting a new annealing operation.

Oxidizable metals treated by this process are specially well suited to be plated with non-oxidizable metals (or galvanized) by reason of the bright, smooth, and clean surface they possess, entirely free from the roughness and foreign element of oxidation.

LUMINOUS NIGHT CLOUDS.

APPEAL is made by O. Jesse of the Berlin observatory for observations of the luminous night clouds which have been annually observed in June and July since 1885. The following description of the phenomenon is translated from the *Astronomische Nachrichten* by the *Astronomical Journal*.

The luminous night clouds are seen only within that portion of the evening or morning heavens which is illuminated by the twilight and separated from the night sky by a more or less washy semicircle, the twilight arch. When they are seen in the evening, it is when the sun is about 10° below the horizon, and they usually remain visible as long as the twilight lasts. In the morning this order is reversed. In their form and structure the luminous night clouds much resemble ordinary cirrus clouds, but they differ from these in some essential respects, by which they can generally be at once distinguished. For if common cirrus clouds are within the twilight segment, when the sun is 10° or more below the horizon, they are always darker than the twilight sky around them; while, on the other hand, the luminous light clouds are always brighter than this sky. Moreover, the ordinary cirrus clouds do not usually disappear when the twilight arch passes by them, so that they are left in the night sky; they only change their aspect in such wise that, whereas they were previously darker than the sky around them, they appear, after their entrance into the night sky, brighter than this is. But the luminous night clouds disappear entirely so soon as the twilight arch has moved past them, and only such portion remains visible as remains within the twilight segment. With regard to the color of the luminous night clouds, it should be mentioned that they glow with a white and silvery luster, which changes toward a golden yellow in the vicinity of the horizon. And furthermore, it is worthy of notice that the phenomenon is not manifested on every otherwise cloudless evening or morning during the season of its visibility, but occurs for the most part with intervals of from 8 to 14 days, and then usually remains visible for several successive nights. For observing it, it is requisite that the horizon in the direction of the twilight be as free as possible. Electric and gas light generally interfere with its perceptibility.

[SCIENCE.]

THE UNITED STATES—THEIR GROWTH IN POPULATION IN TWO HUNDRED YEARS.

IN 1798, eight years after the first census of the United States was taken, Malthus, in England, published his "Treatise on the Law of Population," which excited great interest, and brought the author much hostile criticism. In June, 1890, we shall take the eleventh census of the United States, and will know with certainty what has been our increase in a hundred years. We expect to find a population of 67,240,000. Malthus held that population in a wide country, affording plenty of space and producing abundant food, doubled every twenty-five years. Trying his estimate by the recorded figures of ten decennial census enumerations, we find that he was very nearly correct.

With the aid of this information, we attempt to discuss the results to date, and to infer something of the progress of the next hundred years. We do not think it rash to infer the work of a century from the known advance during one just expiring. Taking the figures of the past from "Johnson's Cyclopedia," we find the population of the North American Colonies estimated by Bancroft as follows:

Year.	Population.
1750	1,260,000
1754	1,425,000
1760	2,195,000
1770	2,312,000
1780	2,945,000

The following table shows the rate of increase since 1790, as shown by the census returns:

Year.	Population.	Increase in 10 Years.
1790	3,929,214	
1800	5,308,483	35·1 per cent.
1810	7,239,881	36·3 "
1820	9,633,822	33·1 "
1830	12,866,020	33·5 "
1840	17,069,453	32·6 "
1850	23,191,876	35·8 "
1860	31,443,321	35·6 "
1870	38,558,371	22·6 "
1880	50,175,000	36·0 "
1890	67,240,000	34·0 "

The mean of the rates is 33·46 per cent. If we substitute for 22·6 (the exceptional rate of the increase between 1860 and 1870) 34·8 per cent. (a mean between the rates immediately preceding and following the decennial epoch), we find as probable rates of increase and aggregates of population, had peace continued, the following:

Year.	Population.
1870	42,380,000
1880	57,130,000
1890	77,100,000

This is 9,860,000 more than the population actually to be expected in the next census—loss to be attributed to a great war. Other variations in the decennial rate of increase are due to the war of 1812, the Mexican war, the cholera epidemics, etc., and to emigration.

In estimating the progress of population during another century, it is not perhaps rash to assume a rate of 33·3 per cent., which is a little less than the mean rate, including war and pestilence, which has ruled our growth in the last century. Adding one-third to each decennial estimate, we find the probable population to be as follows:

Year.	Population.
1890	67,240,000
1900	89,653,333
1910	119,737,777
1920	159,650,377
1930	212,867,177
1940	283,822,877
1950	381,763,837
1960	509,018,449
1970	678,691,265
1980	904,921,686
1990	1,206,562,248

This completes the century. Then, as the area of the territory of the United States is 3,026,494 square miles, the density of its population in 1990 will be 399 to the square mile. The density of population in certain countries is given in the same cyclopedia (printed in 1878) as follows: United States, 12·7 per square mile; Atlantic States, 46·6; basin of the Ohio, 37·7; Massachusetts, 201; Ohio, 66; Belgium, 434; China, 420; England, 389; Europe, 71; Asia, 46; Africa, 16; America, 6; Australia, ½. Such a nation will have a power and a commerce and industry not heretofore known to the world. Our ships and those of our allies will bring the spare products of every land to our shores. Systems of interior land and water transport, perhaps mostly operated by electric power, will rapidly and cheaply distribute them.

For a century we may hope to live comfortably and abundantly within our boundaries. But other people must grow also. The now empty and waste places of the earth will be occupied by civilized and industrious nations. We have in this generation made wonderful and rapid progress in the discoveries and inventions of science. We use the electric force, as did our fathers that of steam. In all probability, electricity will heat as well as light our houses, and will cook our food. It will drive other as well as our city passenger railroads. And it is not probable that man has yet discovered all the resources laid up by the Creator to be discover-

ed and utilized by his creatures when needed for their happiness and comfort.

The Anglo-Saxon race will occupy the continent from the Isthmus to the Arctic, and, when crowded therein, must spread over South America, or perish. That they are not likely to submit to. As the prairie wolf disappears when man drives off or subjugates the animals on which he lives, and for whose regulation he appears to have been created, so will the weaker races give way to the stronger. It has been thus in all history, and the law still holds. There are in the United States a majority of whites over blacks of 51,000,000. They will be able to settle without bloodshed most of the apparently troublesome questions as to races, as may to them seem best; and when they agree upon the methods, and necessity enforces the duty, they will settle them for the best good of the greatest number.

Soon after the civil war it was often said that they who believed in the success of the United States, and conducted their affairs on the theory of such success, grew rich and prospered. They who took the opposite belief were unsuccessful, and lost their fortunes. Those who believe in the prospects here set forth will rule their undertakings and investments in the expectation that property in real estate must advance in the next half century; that commerce and transportation and production must increase enormously. As the discoveries and inventions of science and industry make towns more and more healthful, convenient, interesting, and agreeable places of residence, our people will tend more and more toward them. Museums, libraries, public halls for the education and instruction and amusement of the people, will be more and more numerous and cheap. The streets and parks will be embellished and made gay with public and private buildings. Electric engines will do the heavy work of the day. More time will be at the disposal of men for enjoyment, as these improvements relieve men and women from slavish toil for the means of living.

It may be assumed that the cities will grow at least as fast as the country. In 1790 the urban population was estimated at one-thirtieth the whole; in 1840, at one-twelfth; and in 1870, at one fifth. In 1990 the urban population will be 246,000,000; and of these, New York will probably contain over 30,000,000. What will be the value of lands in that city then may be inferred from the auction sales of London, which has 4,000,000 people. But there is here an inexhaustible field for investigation and speculation. We leave it to others to explore, having fulfilled the task we set ourselves, of calling the attention of those who inaugurate or direct great enterprises to the need of looking, in arrangements for the future, to a longer period than the decennial census, which is the limit of all speculations on the subject of population and growth which I remember to have seen in print. Twelve hundred millions of intelligent, educated, industrious people, of one race and blood, under one free government, armed with all that science teaches and man has invented—who will wish to interfere with their happiness? Who will attack them?

The probable increase in the ten years from 1930 to 1940 will be about 68,000,000. This is equivalent to 13,600,000 families. Considering only the building trades, this will require the construction in ten years of 14,000,000 new domiciles or family residences. Each will need as much floor and window area as now. Does any one yet foresee the volume of business and its activity, in constructing within a single decade as many buildings as at this time exist within the limits of the United States?

What work for architects, contractors, builders, carpenters, masons, bricklayers, plasterers, brickmakers, quarriers, saw mills, lime kilns, sand gatherers, rolling mills for structural and roofing iron in sheets and beams, for tinners and roofers, and the thousand other trades engaged in construction, not only of the 14,000,000 new homes, but of the markets, stores, warehouses, post offices, court houses, city halls, jails, penitentiaries, etc., necessary in the administration of an additional population equal to all that exists now on the northern continent! What will be the work of providing, and delivering at every house, three meals a day, and every day, for each inhabitant thereof?

M. C. MEIGS.

THE NEW MUSEUM OF NATURAL HISTORY, VIENNA.

THE Museum of Natural History in Vienna, opened by the emperor recently, is situated, says a correspondent of the *London Daily News*, in the square which faces the Ringstrasse, opposite the Burg Palace, and the center of which is occupied by the monument of Maria Theresa, unveiled more than a year ago. The museum has a frontage of about 570 feet, is 77 feet in depth, and covers an area of nearly 13,000 square yards. Its height is about 88 feet, and the central part of the building is surmounted by an "attika," 15 feet high, out of which rises the dome or cupola, which is almost 110 feet high. The crowning point of the building is a colossal statue of Helios, the top of which is nearly 320 feet from the ground. The building is divided into four stories—a low ground floor containing the apartments of the directors and the rooms in which objects are to be prepared and repaired for the collections; a lofty ground floor, where are placed the mineralogical, geological, prehistorical, and ethnographical collections; the first floor with rooms of extraordinary height, containing the collections of animals; and a second floor for botany, and a beautiful anthropological collection, comprising skeletons of all races and several thousand skulls.

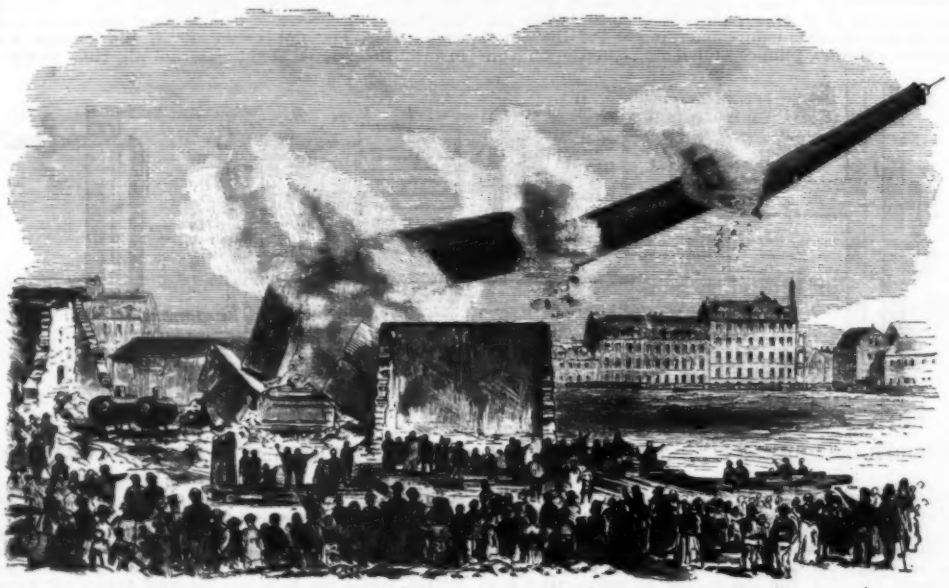
It will be difficult to understand that though the list of ornaments is a long one, the beautiful building is not overburdened with decoration. On the square plateau forming the base of the cupola, which, as has been said before, is surmounted by the statue of Helios, are four colossal sitting statues of Hephæstus, Gæa, Poseidon, and Urania, as the representatives of fire, earth, water, and air. A marble balustrade surmounts the entire building, and upon it are placed at regular intervals thirty-four statues, about ten feet high, of men famous in science. The collection is completed by sixty-four busts of men learned in natural history, placed in niches above the windows of the second floor, their names being engraved on red marble tablets below the windows. There are, moreover, marble reliefs above the windows of the first story, medallions over those of the second, and niches with allegorical statues at either side of the great gates. These represent the history of the human understanding of nature. They begin with mythology, shown by genii driving butterflies and riding on dolphins, and pass to the dawn of science in the representations of Phryxus and Helle, and Hercules and Atlantis—whom Greek legend represents as having crossed the ocean as far as the Hellespont and the columns of Hercules respectively—and Jason. Time and space are next shown, the first by figures symbolizing present, past, and future, the latter by embodiments of height, breadth, and length. Then follow the six days of the creation, with statues of Noah, the preserver of men and animals; Moses, as showing the Semitic views of nature; all the gods of mythology and all the continents, and lastly a group comprising Alexander the Great, who disclosed the East to ancient culture; Cæsar, who opened the north, and among modern discoverers Columbus, Vasco de Gama, Newton, Kepler, Magellan, and Captain Cook.

Three enormous cast iron gates, reached by a number of broad granite steps, lead into the vaulted vestibule, in the center of which there is a circular opening giving a view of the great dome. From the vestibule, which is paved in black and white marble, two small flights of steps lead to the ground floor to the right and the left. Opposite to the three gates rises the great staircase, which has been adorned with the utmost profusion. All the steps are formed of white marble monoliths six and a half yards broad, the sides are of yellow marble framed in darker stone, bearing the cipher of the emperor in bronze. The ceiling shows Canon's last great work, *The Course of Life*, which is not a frescoed painting, but probably the largest canvas in the world. It represents work, love, wealth, renown, and power rising upward and defeating hatred, greed, shame, and despair. The center is occupied by a sphinx impassive to all the turmoil around, and the genius of time, a bearded old man, which figure is a portrait of the painter. The twelve semicircular niches on the walls of the staircase are filled by twelve canvases by the same hand. They represent all the sciences in allegorical figures. Eight white marble statues more make this staircase a veritable temple of art. They are Aristotle, Kepler, Newton, Linnæus, Abraham Gottlob Werner, Cuvier, Berzelius, and Alexander von Humboldt. The vestibule on the first floor has a gilt railing round the opening in the ceiling of the ground floor. It is adorned with marble figures of zoology, botany, mineralogy, geology, ethnography, and anthropology. A frieze with representations of all kinds of animals surmounts the walls.

The great defect of all museums, lack of space, is absent here, and in this respect the Museum of Natural History in Vienna has not its equal. Though the building was completed in 1881, its foundation stone having been laid in 1872, it was not opened till quite recently, so long did the internal arrangements and the placing of objects which were brought from the Burg Palace take up. The collections are the private property of the emperor, and the first beginning was made one hundred and forty years ago, when the Emperor Francis I. bought the fine collection of the Florentine, John Baillon, and made him director of the young museum. The imperial collections were extended so quickly that additions had to be made to the palace to make room for them, but everything was crowded into narrow and dark rooms, so that it became absolutely necessary to build a museum for them.

THE FALL OF A FACTORY CHIMNEY.

THE accompanying cut illustrates the fall of a great chimney as it was recently seen by a crowd at Neustadt, near Leipsic. In consequence of the removal of the steam saw mill of Bassler & Bomnitz, the factory buildings, including the two large chimneys, had to be pulled down. The chimney shown in the illustration was about 90 feet high, 48 feet in circumference at the base, and the walls were 4½ feet thick. In order to cause the fall of this colossus, a portion of the lower part had to be broken out, an undertaking which was made very difficult and tedious by the strength and resisting power of the material. At last the opening was increased to such an extent that the crack which started in the opposite side widened perceptibly. The high column began to totter; and gradually it bent majestically as if it wished to lay out its full length. Then the masonry of the rear wall of the foundation was pressed in, and in consequence of the jar thus given it, the column broke at about one-third of its height, and with this new jar the upper part also split off and the three separate masses fell to the ground. A great cloud of dust and soot covered the region for about a minute. The crowd that gathered to see the overthrown giant found only a confused heap of stones.—*Illustrirte Zeitung.*



FALL OF A FACTORY CHIMNEY IN NEUSTADT, NEAR LEIPSIC.

ZOOLOGY A HUNDRED YEARS AGO.

THIS was the subject of the recent presidential address by M. De Lacaze Duthiers, before the French Association for the Advancement of Science, at Paris. We give an abstract from *Nature*.

"When 1789 came, Linnæus and Buffon had just died and their fame was at its greatest splendor. They were the absolute masters of zoology, and the whole science was summed up in their work. Yet how different were the two in their nature and their work.

"Linnæus, precise, methodical, a classifier above all, introduced clearness and order into the most minute details of natural history, and as he proposed a nomenclature at once simple and precise, his influence acquired such a preponderance that Von Haller complained of his tyranny. If the reform of scientific language proposed by Linnæus took such immediate and powerful hold on the scientific world, it was because it exactly corresponded to the need of the moment.

"Before Linnæus, the objects of natural history were designated by the help of names or phrases formed by the addition of adjectives describing their characteristics, which overburdened the memory. All this he reduced to two words, just as in our families we distinguish the various members by a family name and a Christian name. The simplicity, the ease of application, and above all the opportune appearance of his nomenclature, were the causes of its great success: but we must add that its intrinsic value is such that even to-day we hardly depart from the rules on which it is founded.

"The opposite of Linnæus, Buffon delighted in broad delineations, and his general reflections were animated by a potent inspiration. We are carried away and enthralled by the profundity of his thought, the elevated standpoint from which he views science. By reasoning and the consequences of observations which he interprets, he seeks as much to discover what will take place, and what must have taken place, as to determine the exact nature of what he observes. And thus he was often in advance of his epoch, and his lofty views could be understood only by the few.

"Linnæus, on the contrary, established *facts* with simplicity and clearness.

"With qualities such as these, these two men of genius, who died toward the end of the last century, must often have been at variance; and though the name had not yet been pronounced, we may already at this epoch distinguish between the school of facts and the school of theories (*l'ecole des faits et l'ecole du raisonnement*).

"But there was wanting to the works of Linnæus and Buffon a foundation whose necessity made itself imperatively and universally felt. For it was beginning to be perceived that the study of the habits, of the geographical origin, and of the external characters of animals was not sufficient.

"Then came Cuvier. It was the great merit of Cuvier to see clearly that if zoologists would arrive at a truer knowledge of animals, they must not content themselves with a description of their external forms, but must investigate their internal construction. It was thus that he introduced the notion of *anatomy* into natural history."

M. De Lacaze Duthiers proceeded to defend Cuvier's memory from unjust attacks which it had suffered owing to his opposition to Lamarck.

"Let us not judge great men by their weaknesses. By wishing to depreciate them, we often arrive at a contrary result, and lessen ourselves by a display of systematic and unjustifiable hostility. Let us see in them only what is good and great. And then we shall not fail to recognize the fact that Cuvier is entitled to our fullest meed of admiration."

The lecturer continued by pointing out that Geoffroy St. Hilaire and Lamarck occupied the same position with regard to Cuvier that Buffon had held with regard to Linnæus. Their speculations were too advanced, they came before their time.

"Zoology remained stationary for many years after

Cuvier, and it was not before the beginning of the century that new ideas sprang up directing research along fresh paths, and profoundly modifying certain branches of biological science.

"It is strange to see how books and observations of considerable value often remain obscure for years, and are then finally brought to light by some unexpected discovery.

"I remember that about the year 1855 Prof. Huxley, the illustrious English *savant*, wrote to me (I was then professor at Lille): 'In England we are all much excited about the discoveries of M. Boucher de Perthes.' You all remember the interest aroused by the discovery of the chipped silexes of St. Acheul and the famous jaw of Moulin Quignon.

"English geologists came to Amiens. The most lively discussions took place, and an international committee was formed to direct an official excavation.

"But perhaps the real discovery made, and this was due chiefly to the journey of the English *savants*, was that of the books, the researches, and the new ideas of Boucher de Perthes, which had hitherto passed almost unnoticed.

"We may say that from this moment dates the study of prehistoric times, which has undergone so immense a development. The excitement produced by the discoveries of M. Boucher de Perthes had begun to calm down, and researches were being pursued in every direction, when the first of Darwin's essays appeared in 1858 and 1859. These dates will remain forever memorable in the history of natural science, for henceforward zoology (the only science of which I am at present speaking) takes an entirely new direction.

"We must acknowledge that whatever the measure of confidence we have in the theory of transformism, if we admit it to its full extent, with all its consequences, or if we reject it, it can be a matter of doubt to no one that this theory has led to a truly extraordinary scientific activity. Partisans and detractors both, in seeking for proofs of their opinions, either in the mysteries of embryology or in the investigation of the animal remains in geological strata, all, whatever their method, their ideas, their opinions, or their hostility, have caused zoology to take great strides.

"How far removed we are from the time of Linnæus, when external characteristics were everything—from the time of Cuvier, when anatomical notions and the study of exterior forms alone guided the classifier.

"To-day, what we seek for first of all is the enchainment of animals, either by going back to the forms of the past from those of the present, or the converse. We seek to explain the varied forms we see by the laws so happily formulated by Darwin—laws, indeed, which are as true as they are seductive.

"Who can deny the struggle for existence? Is it not to be found everywhere? And who will not admire the effects of selection? But why exaggerate its true bearings?

"Evolution is to be met with everywhere in the civilized world as in the world of nature, development is the great and eternal problem, resolved by the destruction of some, by the advancement of others; everywhere the struggle for life shows itself, inflexible and fatal.

"One may be a partisan or not of the theory of evolution, and I have not here to declare my own opinions, but rather to determine the exact influence of certain discoveries and certain men on the progress of science, but one is forced to bow to facts, and to acknowledge the magnitude of the prodigious impulse given to science by the great English naturalist. But, as Claparede would say, there are *enfants terribles* of evolution, men more anxious to be spoken of than to discover the truth.

"We must carefully distinguish them from the conscientious men of science who investigate precise facts patiently, scrupulously, and laboriously to deduce from them consequences in support of their theory. Men such as these make science advance surely, whereas the others sometimes compromise the cause.

"The only thing to oppose to exaggeration, the influence of excessive enthusiasm, is recourse to *experiment*. To-day, that is the great reform which we feel to be as necessary as those other reforms of whose history I have spoken."

Before developing this idea the lecturer spoke of Lamarck, and of the reason why his ideas were not adopted during his lifetime.

"Of late years people have thought they had rediscovered Lamarck, and have severely blamed the generation of zoologists who neglected for half a century the author of the 'Philosophie Zoologique.'

"It is true that in the works of Lamarck there are whole pages which contain the theory of transformism completely developed, to which Darwin has added nothing, and which we may say he has but confirmed.

"But if Lamarck had not the satisfaction during his lifetime of seeing his ideas admitted, it was that the minds of zoologists were not sufficiently prepared for them; it was that he had not the rare good fortune of finding a precise and lucid formula, whose truth is evident, and which is necessarily accepted by all.

"Some of Lamarck's conceptions of nature are even difficult to understand, and especially to make clear to others; and I do not see that even his most ardent admirers have insisted on this portion of his work, and yet it is by no means inconsiderable.

"We should have been glad to see it more clearly explained than it is in the original, and brought within the comprehension of all, and one wonders why it should never be referred to.

"For a reformer to succeed, his idea must be striking in brilliancy and precision; it must master us by its intrinsic seduction.

"Take Darwin, showing us the struggle for existence taking place everywhere and at every instant, and leading to the selection and survival of the victor.

"Take Cuvier, who, it was said, reconstructed an extinct animal from a fragment of bone. A statement like this appealed to the imagination of the masses, and he excited the admiration of a whole generation when he compared an organism to an equation of which we may determine the unknown by the known quantities it contains.

"If Lamarck did not have the success he deserved, it was because of the abstract form he gave to his opinions, and the often *naïve* proofs which he adduced in confirmation of his theories at a moment when enthusiasm and popular attention were diverted to another aspect of science.

"Lamarck was, moreover, regarded as a visionary because he believed in the possibility of forecasting the weather from observations of the atmosphere and of the forms of clouds, and yet who would now blame him for his hopes?

"Lamarck was a man of genius who foresaw the advances of science on many sides, but who did not possess the faculty of being able to present his ideas in a felicitous form intelligible to his contemporaries."

The lecturer then retured to his theme, that experimental research in zoology is the need of the hour, and proceeded to give some striking examples of the results to which it has led.

First, he described the alternation of generations in the gall-producing insect, whose two forms were originally known as Biorhiza and Teras. The Biorhiza, a wingless and asexual form, is born from eggs laid in the roots of the oak; it crawls up to the branches, and there causes the gall excrescence as it lays its unfertilized eggs. From these eggs issue the sexual winged form Teras, which conjugate; and the female then lays her eggs in the roots of the oak, and from these spring the Biorhizæ. He then spoke of the strange metamorphoses of a certain insect *Sitaris*, semi-parasitic on a species of bee, *Anthophora*, which have been investigated by M. J. H. Fabre, and of those of the lobster. In all these cases, forms supposed to have been different have proved to belong to the life history of one and the same animal.

"It is because zoology is at this moment at a critical period, and because of the positive nature of the affirmations made by the partisans of transformism, that the methods of the science must be modified, and that besides simply registering the existence of species, we must have constant recourse to the test of experiment. Such is the conclusion at which we logically arrive, and which to-day, I repeat, has become imperative.

"I have sought to point out to you the considerable part which our country has played in the progress of the natural history of man and of animals during the century which is drawing to a close.

"I should have wished to speak also of the origin and development of other branches of biology, of comparative and general anatomy, of experimental physiology, anthropology and palæontology. But I think I have said enough to show that I am justified in spurning the reproaches and inimical accusations so often made against us, that France is a country in which scientific work is on the decline, and whose decadence is at hand.

"We open our meeting full of joy in the present, of hope for the future, in presence of the imposing spectacle whose success has but increased since it began in May, and which demonstrates the inanity of these accusations. Let your labors, varied as they are important, prove once more, during a year so fertile in pacific manifestations, that we work only for the restoration of our country, and that the peace of which others speak much, and perhaps believe in but little, is the sole preoccupation of all men of sense, of all who are in earnest in this country of France—France whose desire is to remain free and independent, ever animated by the most generous and patriotic of sentiments."

At the conclusion of M. Lacaze Duthiers' speech, which was most enthusiastically cheered, the treasurer announced that the receipts for the year had been £3,760, the expenses £3,480, and that the total capital of the Association amounted to £33,060. An important legacy of about £7,000 had been bequeathed to the Association by M. Girard, for the promotion of researches on prehistoric man.

The proceedings concluded with a report on last year's meeting at Oran, and the members then adjourned to the Ecole des Ponts et Chaussées, where the sectional sittings took place.

The French Association is subdivided into seventeen sections and subsections: (1 and 2) Mathematics and Astronomy; (3 and 4) Civil and Military Engineering and Navigation; (5) Physics; (6) Chemistry; (7) Meteorology; (8) Geology and Mineralogy; (9) Botany; (10) Zoology, Anatomy, and Physiology; (11) Anthropology; (12) Medical Science; (13) Agriculture; (14) Geography; (15) Political Economy; (16) Pedagogy; (17) Hygiene.

An immense number of papers were contributed to the sections. We may mention: (sections 1 and 2) M. Joukowski, on an apparatus for determining moments of inertia. (3 and 4) M. Pichou, on a universal paddle wheel. By altering the direction of the paddles, a steamer may be reversed without reversing the engines. (5) MM. Baille and Feret, on a method for reading the oscillations of the balance with great precision; the authors employ a very simple optical arrangement, which allows them to estimate the 1/2000 part of a milligramme by the displacement of a series of Newton's rings. (6) MM. Alexeieff and Werner, on the heat of neutralization of certain aromatic compounds. The authors show that the general results already acquired enable one to determine in certain cases the position of disubstituted compounds. Messrs. Gladstone and Perkin, on the relation between constants of refraction, dispersion, and magnetic rotation in organic compounds. M. Cazeneuve, on camphor derivatives. M. Franchimont, on the action of nitric acid on organic bodies according to their function. M. C. Chabrie, on the synthesis of selenium organic compounds. M. Raoult, on a new form of the apparatus for cryoscopic observations; the author produces cold by the evaporation of carbon disulphide. M. Meunier, on insoluble crystalline compounds of mannite and sorbite, with the aldehydes, serving to isolate these bodies from organic mixtures (the juice of fruit, etc.) M. Berlinerblau, on a sweet body, NH_2. CO. NH. C_6H_4. OC_2H_5. M. Istrati, on new general methods for the synthesis of aromatic compounds. (7) M. Crova, on the standardization of actinometers. M. D'Abbadie, on the qobar. M. Angot, on the representation of the variation of temperature by a harmonic formula. (8) M. Szabo, on the opal mines of Hungary. M. Malaise, on the Belgian Olethamias. M. Bleicher, on the glacial formation of the Vosges. (9) M. Timiriazeff, on the *role* of light intensity in the assimilation of carbon by plants. M. Mer, on variations of structure in the wood of pines. M. Clos, on certain cases of hybridity in plants, and on the vegetation of *Marchantia polymorpha*. (10) M. De Lacaze Duthiers, on the fusion of nerves and ganglia in mollusca, and on the interpretation of the membrane which separates them. M. Beauregard, on the cetacean ear. M. Packard, on the distribution of the organs of taste in insects. M. Sirodot, on the dentition of elephants. M. Jourdain, on the necessity of conjugation for the continued propagation of protozoa. M. De Varigny, on the action of certain convulsive poisons on *Carcinus mœnas*. (11) M. A. Bertillon, on the anthropometric characteristics of the French nation classed by the departments. M. V. Schmidt, on the Stone Age and the prehistoric Iron Age in Denmark. M. De Mortillet, on right and left handed individuals in prehistoric times. M. Manouvrier, on anthropometric researches on natives of Algeria. Dr. Maurel, on the relation of the section of the thorax to the height and the length of the foot. (12) M. Masse, an instrument for determining the position of the fissure of Orlando. M. Steinhaus, on the causes of suppuration. M. Jolly, on the use of iodine in tuberculosis. M. Luys, on the pathological anatomy of madness, and on the action of rotating mirrors on the nervous system. M. Michel, on the influence of drinking water on public health. (13) M. Kunckel, on the destruction of locusts in Algeria. M. Ladureau, on a rapid method of colorimetrical analysis for nitrates. M. Deherain, on the loss and gain of nitrogen in arable lands and on the graphic representation of crops. (14) M. Castonet des Fosses, on the future of the negro race. M. Gauthiot, on a route for mining exploration from Bangkok to Korat. The Prince of Monaco, on dragging in deep water. M. De Guerne, on an exploration of the Forno de Graciosa (Azores). (15) M. Arthur Raffalovich, on economic legislation in England in 1888. M. Martineau, on the true motives for the introduction of free trade into England. M. Ch. Grad, on insurance against old age and infirmity in Germany. (16) M. Frederic Passy, on a system of writing which permits blind people to communicate with the non-blind; M. Paul Passy, on spelling reform. M. Herzen (of Lausanne), on the organization of certain secondary schools to enable them to continue the teaching of the primary schools. M. Morel, on the organization of the *enseignement special* in the secondary schools of Paris. (17) M. Delthil, on diphtheria and its treatment. M. Teissier, on diphtheria at Lyons. MM. Dubief and Brutel, new experiments on the value of sulphurous acid as a disinfectant.

The work of the sections was most usefully supplemented by visits to different institutions and to the exhibition. Sections one and two inspected the collection of calculating machines at the Conservatoire des Arts et Metiers, under the guidance of M. Ed. Lucas. Sections three and four examined the new steerable balloons with the inventor, Commandant Renard, while various other parts of the exhibition of the minister of war were explained by officers of the special departments. Section six inspected the fine collection of chemical products at the Champ de Mars (Class 45), general explanations being given by MM. De Clermont, Riche, Suilliot, Billault, Istrati, and others. M. Tanret showed his interesting exhibit, including specimens of pelletierine, the alkaloid of the pomegranate bark now so extensively used as a tænifuge, and ergotine, the active principle of ergot of rye, by whose discovery M. Tanret has rendered such signal service to therapeutics; and last, but not least, M. Grimaux, professor at the École Polytechnique, gave an account of the fine exhibition of Lavoisier's papers and instruments, which he had selected from the collection of M. De Chazelles, to whom they belong,* and pointed out the portrait of M. and Mme. Lavoisier, by David, in the Palais des Beaux Arts. Section seven met at the exhibition to see the instruments which record the direction and the vertical and horizontal components of the wind on the top of the Eiffel tower, the results being transmitted electrically to the Palais des Arts Liberaux, and inscribed on MM. Richard's revolving drums. The section also met at the Central Meteorological Office to see experiments on cyclones by M. Weyher. Sections eight, nine, and ten inspected the fine galleries at the Museum, which have just been opened.

Other scientific visits were paid to the Institut Pasteur, the sewers of Paris, and to various glass works, gas works, etc. On Thursday, August 8, the municipality of Paris threw open their magnificent suite of rooms at the Hotel de Ville to the members of the French Association; while extraordinary animation was lent to the scene by the presence of the students of Paris and their foreign comrades, 8,000 guests in all having been invited. On the following evening, the Association was received by M. Yves Guyot, the minister of public works, and Mme. Guyot at the ministry in the Boulevard St. Germain. A concert was given during the evening by members of the Opera Comique; while the gardens lighted up by Chinese lanterns afforded a pleasant change from the crowded *salons*.

On Sunday, August 11, an excursion was made to St. Germain-en-Laye, and to Meudon, dinner being served in the orangery which belongs to the beautiful grounds of the Astronomical Observatory, directed by M. Janssen. M. Janssen offered a warm welcome to the members, and said that he should be very willing to let his observatory be used for the scientific purposes of the Association. On Monday, August 12, a lecture was delivered by General Tcheng-Ki-Tong, on the social economy of China. On Wednesday, August 14, the Association offered a banquet to its foreign members at the restaurant d'Alsace-Lorraine on the first story of the tour Eiffel.

M. De Lacaze Duthiers made a short speech, in which he declared that he would not say good-by to the foreign guests, but *au revoir*, as he hoped to see them all again at the meeting of the Association next year at Limoges. That they did not forget past events was proved by the name of the restaurant in which they met, but he firmly believed that "*Le temps prime la force*," and he drank "to the peace of the whole world."

MM. Van Beneden, Dekterev, Istrati, Hartog, Ramon de Luna, Llaurado, Stephanos, Timiriazeff, and Watson spoke in the name of their respective countries, and drank to the cause of peace and to the prosperity of France.

On Friday, August 16, a general excursion took place to the paper works at Essonne, and to the works of M. Decauville (the constructors of the narrow gauge railway in the exhibition), who offered a lunch to their guests.

Thus concluded this brilliant and successful session of the French Association.

* M. Grimaux has published this year a remarkable monograph on Lavoisier (Felix Alcan).

ON THE PURIFICATION OF ALCOHOL BY MEANS OF HYDROCARBONS.*

By W. S. SQUIRE, Ph.D.

THE purification of commercial alcohol by some ready and inexpensive method is a matter of great importance. The voluminous report of M. Claude, presented in 1887 to the French Senate, accompanied by an exhaustive atlas of the quantity and kind of spirit consumed in different departments of France, demonstrated the great evils which result from the consumption of impure alcohol. Legislation based on this report was contemplated with a view to compel the purification of spirit going into consumption, but useful legislation of any kind is not likely to occur amid the frequent wreck of ministries and the constant struggle of adventurers for place and power.

The German government has also had this question under consideration, and it is probable that legislation in this direction will be attempted ere long. But apart from legislation there is a large actual demand for pure spirit for the manufacture of liqueurs and the common sorts of brandy, for medicinal purposes, and for the fortification of wines.

In Germany, where the spirit industry has attained such development as to be of national importance, the spirit as it comes from the distilleries is very impure. The distilleries are very numerous, and for the most part very small. Indeed in many cases a distillery is part of the regular plant of a farm, the farm laborers being employed during the winter in the distillery working up the potatoes and other matters into spirit, the whole of the residual products going back to the land, either directly as manure or indirectly as food for the cattle. This arrangement is very wisely encouraged by the government, which favors the farmer in the matter of duty, provided nothing leaves the land, except the carbon, hydrogen, and oxygen in the alcohol, which, strictly speaking, were never in the land at all, but have been derived from the air.

It will be readily understood that small distilleries of this kind, at work only half the year, are unprovided with the apparatus necessary for producing a pure spirit. The stills are of comparatively simple construction, and, indeed, very little attempt is made to remove any impurity, except water. This, of course, is removed, so far as it can be easily removed, in order to keep the cost of packages and carriage as low as possible.

The spirit in this impure state comes into the market like peas, beans, or other agricultural produce, a few casks at a time, and is bought by the rectifiers, who have usually large establishments, and work on a considerable scale.

The German rectifier commences his operations by diluting the raw spirit with water until the mixture contains from 40 to 50 per cent. of absolute alcohol. This dilution greatly facilitates the removal of the fusel oil. The dilute alcohol is then filtered through wood charcoal. Lime tree charcoal is preferred, but the charcoal of other light and soft woods is occasionally employed. The apparatus used for this purpose is shown in Fig. 1. The plant consists of a number (usually six or eight) of wrought iron cylinders about three or four meters high, and about 80 centimeters in diameter. These cylinders are filled with wood charcoal in small pieces, and are connected together by means of pipes and cocks to enable the requisite operations to be carried on.

The dilute crude spirit is contained in a tank above the apparatus (not shown in the drawing), and the purified spirit is received in a tank, at a lower level but above the apparatus, shown on the right hand. The cock, A, being open, but the cocks, B, C, and D, closed, as are also the cocks, A^{1-8}, the spirit coming down the supply pipe enters the first cylinder, which it ultimately fills. The cocks, E and F, being closed, the spirit passes down the outlet pipe, and the cock, B^2, being open while the cocks, A^2, C^2, and D^2, are closed, the spirit enters the second cylinder, and the same thing happens to all the succeeding cylinders. In the case of the eighth cylinder the cock, E^8, is open, and the spirit having no other outlet, for the cock, B, is closed, makes its way into the tank intended to receive the purified spirit.

The charcoal in No. 1 cylinder, being in contact with the most impure spirit, becomes first charged with impurities, and this cylinder must be emptied and recharged. In order to do this, the cocks, A and B^1, are closed and the cock, A^1, is opened. This has the effect of cutting out the first cylinder. The cock, D, is then opened, and the fluid contents of the first cylinder run off to be pumped back to the crude spirit tank above. While this is going on the cock, G, which is intended to admit air while the cylinder is being emptied or to allow to pass out when it is being filled, must be open. The cocks, G and D, are then closed, and the cock, C, which admits steam from the steam pipe, and the cock, F, which puts the cylinder in communication with a pipe leading to a condenser, are opened. In this way any residual spirit remaining in the charcoal is given off and recovered. Lastly, the manhole is removed, the charcoal taken out, and a fresh charge introduced through the upper manhole.

No. 1 cylinder is then thrown into circuit by closing E^8 and opening B and E, No. 1 cylinder then becoming the last one. No. 2 is then thrown out of circuit in like manner, and recharged, and so on. Usually seven cylinders are at work while one is being recharged. This apparatus, although largely used, is not, so far as I am aware, figured and described in any work on spirit manufacture. It might be imagined that the vapors driven out of the cylinders by the current of steam, and condensed in the condensers, would contain a considerable quantity of fusel oil. This, however, is by no means the case; the condensed liquid has a nasty smell, it is true, but not such as would be due to a large amount of fusel oil.

Stammer in his large work, "Die Branntweinbrennerei," refers to this fact, and on that account dismisses the charcoal process as being of little use in removing fusel oil; but professors, when they write on technical subjects, are very apt to jump to conclusions on insufficient evidence, and there is one fact of which Stammer must have been aware which does not at all square with his theory. If the fusel oil and other impurities absorbed by the charcoal were driven off in a current of steam, it follows that the steam would revivify the charcoal, and there would be no necessity for recharging the cylinders with fresh charcoal.

That, however, is not the case. It is necessary from time to time to remove the charcoal and heat it to redness in closed vessels. Moreover, we know that charcoal possesses the property of absorbing certain gases, for instance, sulphurous acid and ammonia, in considerable quantity. Now, these gases are nothing more than liquids at temperatures much above their boiling points. It does not, therefore, at all follow that fusel oil, absorbed by charcoal at the ordinary temperature, will be driven off when the temperature reaches the boiling point of the absorbed liquid.

As a matter of fact, the charcoal purifies the spirit very considerably, and manufacturers would not go on using the process if it were found in practice that the spirit came out of the cylinders pretty much as it went in. The purification is, however, not complete. When the purified spirit is rectified in a Savalle rectifier—the apparatus generally employed—an impure spirit, usually about 3 or 4 per cent. of the whole, and containing aldehyde and certain ethers with low boiling points, comes over first.

This is followed by a very pure spirit, usually about 10 per cent., used chiefly for fortifying wines. Then comes the ordinary rectified spirit, and lastly an impure spirit containing impurities with high boiling points. The heads and tails of the distillation, as they are called, are usually mixed together and sold at a

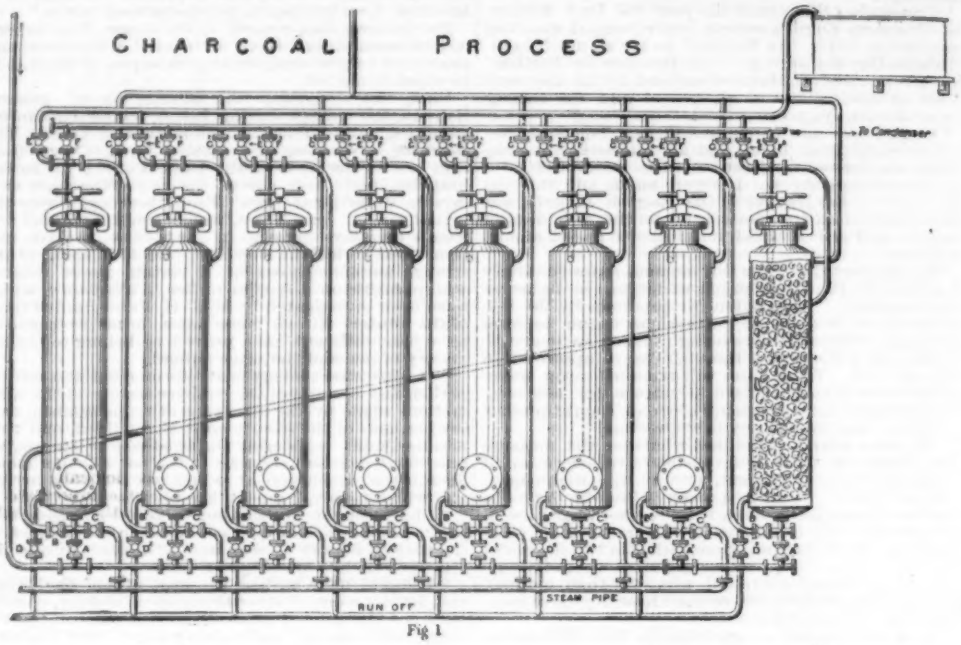


Fig 1

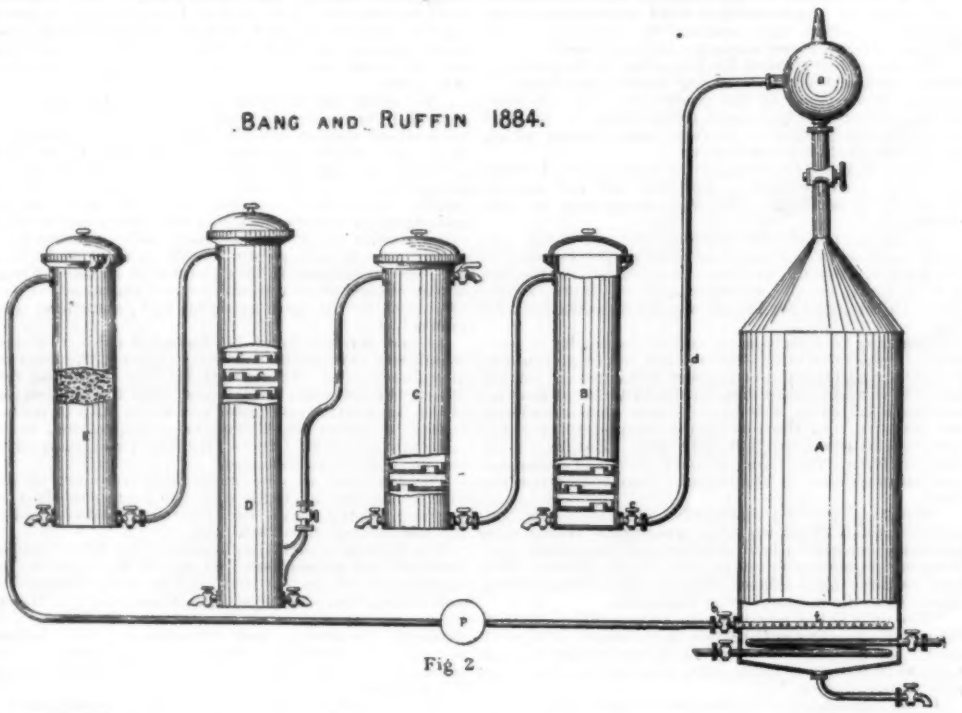


Fig 2

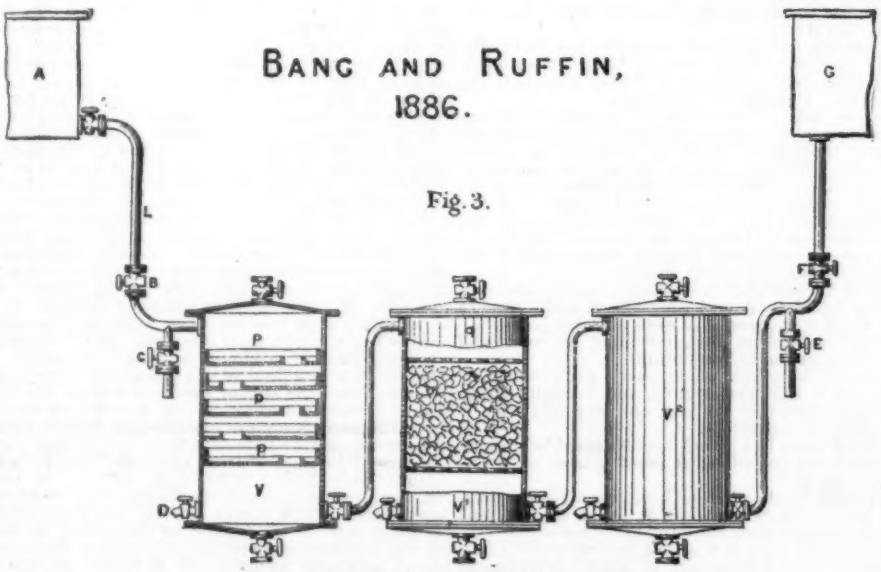


Fig. 3.

PURIFICATION OF ALCOHOL.

* Read before the Society of Chemical Industry, London. From the *Journal* of the Society, June, 1889.

cheap rate, as they obviously contain impurities which the charcoal process is unable to remove.

It has long been known that oils and fats possess the power of absorbing the more or less volatile bodies which we know as odors; the odors of flowers, for example. Some of these odors are very delicate; for instance, those of the violet and tuberose, which cannot be extracted from the flowers without serious injury by the ordinary process of distillation. Perfume manufacturers take advantage of this property of oily bodies

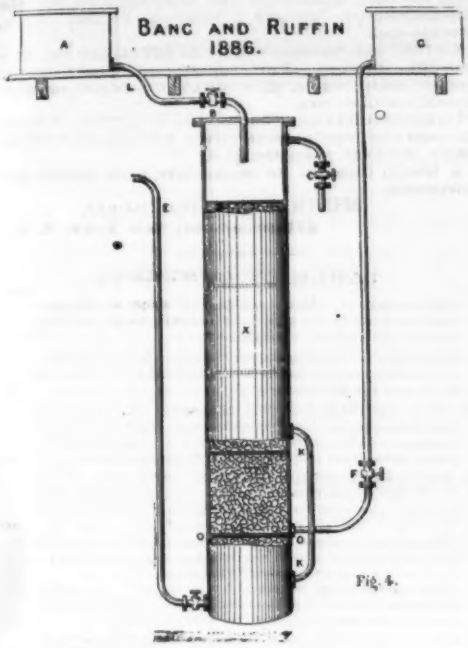


Fig. 4.

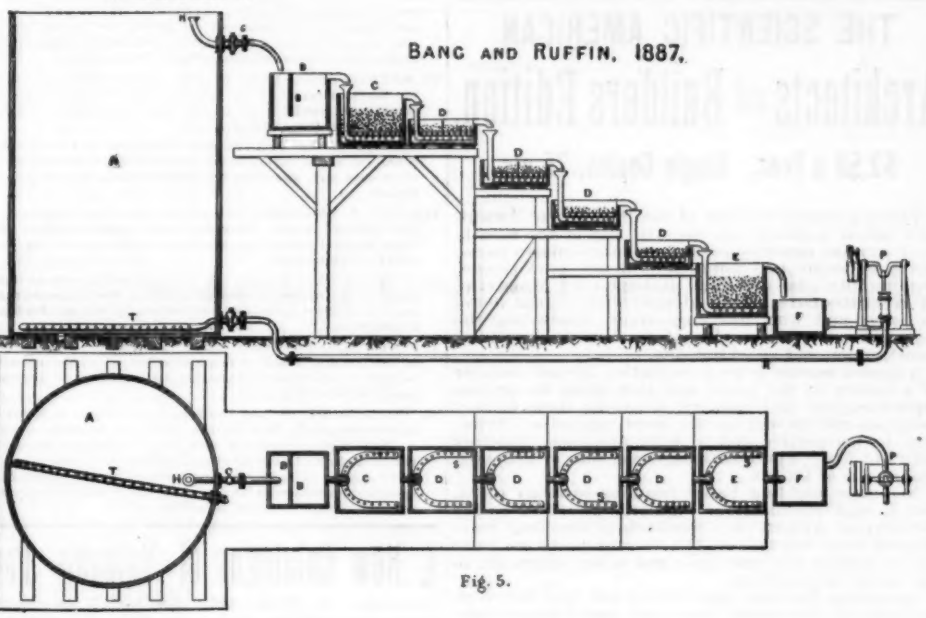


Fig. 5.

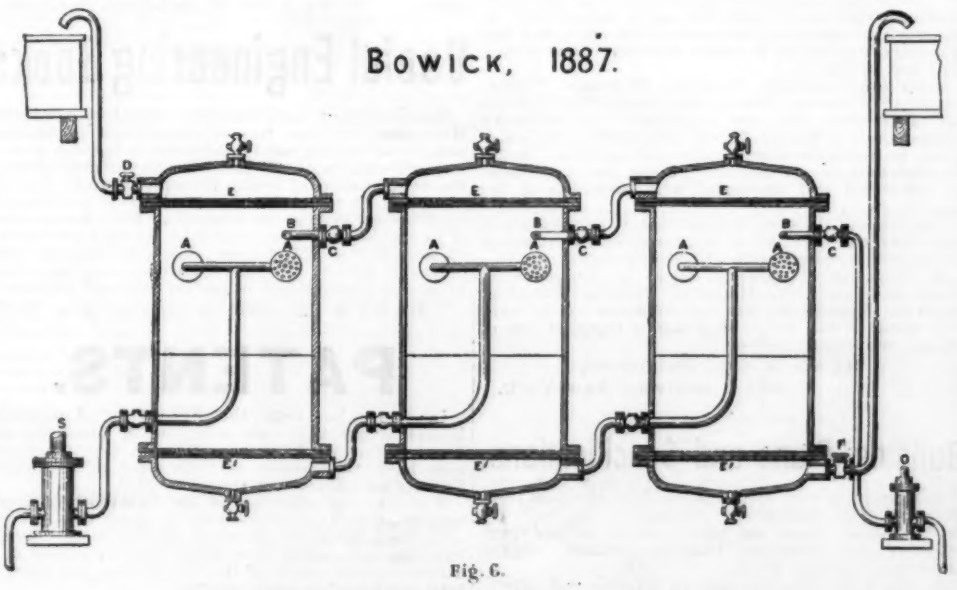


Fig. 6.

PURIFICATION OF ALCOHOL.

to extract the odors without the use of heat. The flowers and layers of pure grease (a mixture of lard and suet) spread on glass are piled up in frames, and after standing some time the odors of the flowers are absorbed by the fat, and may be extracted again from the fats by strong alcohol. This process is called "enfleurage," and is largely practiced in the south of France.

The same general idea has been applied to the purification of alcohol. The first person who experimented in this direction appears to have been Parsons, of New York City, who in 1869 took out a patent for purifying alcohol by means of paraffin. His process consisted in mixing strong alcohol, 90 per cent. at least, with paraffin, and heating the mixture by means of a steam coil with continual agitation. He then introduced warm water, so as to bring the mixture down to about 50 per cent. of alcohol, and allowed the whole to cool with continual agitation. The paraffin, which separated in flakes, was then filtered off from the purified spirit. He states that if the spirit is of less strength than 90 per cent., the purification is less perfect.

In the following year he took out a patent for purifying spirit by causing its vapor to traverse a layer of melted paraffin, and he also claimed the use of mineral oils. So far as I am aware, nothing came of these proposals, and we shall see later on that nothing was likely to come of 90 per cent. alcohol and hot melted paraffin through which the vapor of alcohol was caused to bubble.

In 1880 a patent was taken out by Simon Roessler, of Troppau, Austria, through Messrs. Haseltine, Lake & Co., patent agents, of London, for purifying alcohol, fatty matters, and wax, and for regenerating the materials employed; but whether the object was to purify the alcohol by means of the fatty matters, or the fatty matters by means of the alcohol, I defy anybody to make out. Apparently the inventor wants to do both at once.

In 1884 the subject was taken up by a Danish chemist named Bang, who became associated with M. Ruffin, of Paris. He recognized at once that the alcohol must be treated in a dilute condition. Fusel oil is but little soluble in dilute spirit, but very soluble in strong spirit; indeed, strong spirit actually extracts fusel oil from a mixture of hydrocarbons and fusel oil, while the hydrocarbons extract the fusel oil from dilute spirit. It is a question of relative solubility. I cannot very well show you the fusel oil leaving the dilute spirit and passing to the hydrocarbons, but I can show you something of the same sort which will illustrate my meaning. If I add a dilute solution of chromic acid to a very dilute solution of peroxide of hydrogen, I develop, as you see, the magnificent blue color of perchromic acid. This substance is, as you see, soluble in water, but it is much more soluble in ether. I will add a little ether and shake up the bottle, when the layer of ether floating on the top will become intensely blue, and the water below remains almost colorless. This is what happens when hydrocarbon oils are brought into intimate contact with dilute alcohol containing fusel oils, and other substances more soluble in the hydrocarbon oil than they are in the dilute alcohol.

In Bang's first patent of 1884 he proposed to use as a purifying agent the more volatile portions of petroleum, generally known as essence of petroleum. The apparatus he constructed for the purpose is shown in Fig. 2. The dilute spirit to be purified is contained in a cylindrical vessel, A, and the hydrocarbon is pumped in through the perforated pipe, *t*. The small bubbles of hydrocarbon rise through the dilute spirit, abstracting the fusel oil, and collect in the glass globe, *a*. From this it is conducted into the cylinder, B, furnished with baffle plates, *c c*. This cylinder is filled with water which abstracts any alcohol which may have been mechanically carried over in the hydrocarbon. From B it is conducted to a similar cylinder, C, filled with chloride of calcium to abstract any water it may have taken up. From C it passes into D, filled with strong sulphuric acid, the object of which is to remove the fusel oil and other impurities by the formation of sulpho-compounds. Finally the hydrocarbon is passed through the cylinder, E, filled with pieces of marble in order to remove the sulphuric acid which may be mechanically mixed with the oil.

The hydrocarbon thus regenerated is returned by the pump, P, to the cylinder containing the alcohol to be purified. I may remark, in passing, that if the alcohol is mechanically carried over into B, and water into C, so will solution of chloride of calcium be carried over into the sulphuric acid in D, and that will make a nice mess. And, further, that greasy lumps of marble are not precisely the best means for removing concentrated sulphuric acid.

The use of volatile hydrocarbons being open to many objections, Bang & Ruffin, in 1886, substituted hydrocarbons with a higher boiling point, and devised the apparatus shown in Figs. 3 and 4. A series of cylinders, V, V^1, V^2, are fitted with baffle plates as at V, or filled in the middle with sponge or porous material, to facilitate the contact of the two liquids. These cylinders are filled (says the patentee; I suppose he means partially filled) with the hydrocarbon oil, and the dilute spirit is let in from the cistern, A. It sinks through the hydrocarbon in V, and then passes through the outlet pipe to the top of V^1, when it again falls through the hydrocarbon, passing to V^2, and so on, being finally delivered at the outlet, E. As the hydrocarbon in V becomes charged with impurities, it is necessary from time to time to remove it, and substitute for it that contained in V^1, which is less impure; this in its turn being replaced by that in V^2, which is almost pure. This is accomplished by shutting the cocks, B and E, and opening the cocks, C and F. The hydrocarbon then runs in the opposite direction from V^2 to V, and escapes at C. The hydrocarbon is afterward regenerated by means of sulphuric acid, which takes up the fusel oils by formation of the sulpho-compounds.

A modification of the apparatus is shown in Fig. 4, which consists of a column divided into compartments by means of perforated diaphragms, and filled with porous material. The lower end of this column communicates with the hydrocarbon cistern, C, while the alcohol to be purified is let in from the cistern, A. The discharge pipes, C and E, communicate respectively with the top and bottom of the column. There is also a pipe, K, communicating with the column at two different levels. The column is first filled with water up to the level of the first diaphragm, O O. The hydrocarbon is then run in till it overflows at C. The dilute alcohol is now admitted by opening the cock, B, and descends by gravity through the oil, driving the water before it, and making its exit at E. The hydrocarbon is renewed by stopping the flow of alcohol, and letting in the oil from G.

These apparatus, apparently methodical in their action, are open to a good many objections. Constructed as they are, the alcohol will be very prone to go down all in one place, and this will in nowise be prevented by the perforated diaphragms so liberally introduced. I have often been struck by the unreasoning way in which perforated diaphragms are introduced into chemical plant. A whole chapter might be written on the use and abuse of perforated diaphragms. Let us suppose a fluid arriving through an inch pipe and assume the perforations to be an eighth of an inch in diameter; then 64 holes will equal the area of the pipe (the friction when thin plates are employed may be neglected), but instead of 64 holes there are usually about 640. Even if the pipe runs full bore the liquid will run through a comparatively small number of holes just where the liquid falls, but the pipe rarely runs full bore. There is usually a cock introduced to "regulate the flow," so that as a distributor the perforated plate goes for nothing. A perforated diaphragm should be so constructed that it opposes such a resistance to the flow of the liquid that the whole of the liquid cannot get through the holes until a certain head accumulates, and in virtue of the pressure of this the flow through the holes is accelerated until an equilibrium is established, and only in such a case will every hole deliver the same quantity, and act as a distributor. It is obvious, too, that the oil will be mechanically carried along with the spirit when the spirit flow is on, and the spirit will be mechanically carried along by the oil when the oil flow is on, and further that the impure oil hanging about the porous substance will not be carried on by the general flow of the oil, so that the apparatus is by no means so methodical as it looks.

That the apparatus was open to some such objections as I have named seems probable, for in the following year, 1887, Bang & Ruffin took out another patent for an apparatus shown in Fig. 5, which is, I believe, the apparatus now used by their company at their works near Paris. In this apparatus all attempt at methodical treatment is abandoned. The dilute alcohol to be treated is put into a large vat, A, and the hydrocarbon oil is pumped in by the pump, P, through the perforated pipe, T, thus reverting practically to the original arrangement. The bubbles of oil rise by gravity to the top of the vat, and the oil which collects runs off through the parachute pipe, H. The oil passes next to the vessel, B, where "the oil descending on one side of the partition and ascending on the other, deposits in B some of the heavier impurities carried over by it," whatever that sentence may mean. From B it overflows into C, ascending in streams through a perforated pipe and a perforated floor, through water, to remove any alcohol mechanically carried over, and then through D, D, D, D, provided also with perforated pipes and perforated floors, and

filled with preces of glass, where it is treated with strong sulphuric acid. Then on to E, where it encounters a solution of soda (the marble business, I presume, not being found to answer), and finally into the reservoir, F, from which it is pumped back to the vat, A. During the operation the sulphuric acid is moved upward successively from the lower to the upper vessels, D, but it has to be bucketed up in jugs, an operation which is neither neat nor handy. I should mention that the dilute spirit in A is made alkaline in order to resinify any aldehyde that may be present.

One of the chief objections to this process is that it is very slow. Something like 48 hours at least is required for the purification of the alcohol. At the beginning the oil is largely contaminated with fusel oil, but as the operation goes on it takes out less and less, and yet has to go through the same process of regeneration. It is like washing out completely a voluminous precipitate, and then having to boil down all the endless wash waters. Every chemist knows what a ghastly operation this is. I say nothing of the bucketing up of the sulphuric acid, but after what I have said about perforated false bottoms, it may be doubted whether the distribution in the vessels, D, D, D, D, is very effective.

In 1887 Bowick attempted to meet these difficulties by the construction of an apparatus which should be perfectly methodical in its action, and yet free from the objections to Bang & Ruffin's 1886. His apparatus is based on the principle that if we take a fairly intimate mixture of dilute alcohol (or water) and hydrocarbon oil, and pour it on a filter wet with oil, it is only the oil which passes through, leaving the dilute alcohol behind, while if the mixture is poured on to a filter previously wet with dilute alcohol (or water) only the dilute alcohol will pass through, leaving the oil behind.

The arrangement is shown *diagrammatically* in Fig. 6. It consists of a series of cylinders, all precisely similar, connected together as shown. Each is provided at the top and at the bottom with a filter, E, E^1. These are supported by perforated metal plates, not for the purpose of distribution, but simply as supports. These vessels are filled about one-third with water or purified dilute alcohol (this wets the lower filter), and are then filled up with the hydrocarbon oil (this greases the top filter). The outlet cock, D, for the oil being closed, and the outlet cock, F, for the spirit being open, the dilute spirit is pumped in, by means of the pump, S, through the roses, A, placed horizontally, so as to give a rotary motion to the contents of the cylinder. Under these circumstances a species of emulsion is formed, which, being somewhat heavier than the oil, slowly descends until it reaches the bottom filter, where it is separated into the dilute alcohol, which passes through, and the oil, which rises to rejoin the layer of oil above. The same process takes place in each successive cylinder, and thus the spirit coming in contact with oil always purer and purer issues in a constant stream at F, deprived of all those impurities which the oil is capable of absorbing. As in Bang & Ruffin's 1886 proposal, it is necessary occasionally to displace the oil in the opposite direction. To do this the spirit pump is stopped, and the oil pump, O, set to work, the cock, F, being closed and the cock, D, open. The upper filters then come into play, and prevent any of the dilute alcohol being carried over mechanically by the oil. In order to make sure that the two liquids shall only travel in the prescribed direction, back pressure valves, C, C, C, are introduced. The oil is regenerated by simply blowing through it a current of steam, which carries off the whole of the fusel oil. This can be condensed and collected. As there is a strong demand for fusel oil at a price higher than the price of spirit, this is a decided advantage over the destruction of the fusel oil by means of sulphuric acid.

The oil employed is one which boils at or about the boiling point of mercury, so that there is no danger of any being vaporized with the spirit. It is perfectly destitute of taste or smell. It dissolves fusel oil with the greatest ease, and is therefore well fitted for its removal; and I believe that this process is a good one for the removal of fusel oil.

The advantage of Bowick's apparatus is that it permits a far greater subdivision of the oil, and therefore more intimate contact without any danger of the oil being mechanically carried along in the stream of spirit, or the spirit in that of the oil. It is, moreover, perfectly methodical and continuous in its action, and, in consequence, the oil is always charged to the fullest extent with impurities, and there is no oil weak in impurities to treat, as in the latest Bang & Ruffin. Even with the Bowick apparatus it is not advisable to go too far in the subdivision. If the particles of oil are more minute than the pores of the paper they will go through, just as milk does. But if the pressure and the size of the openings in the roses are properly adjusted, very great subdivision may be attained, with complete separation by the filters.

Whatever apparatus is used, the result in the end must be the same. If you go on treating dilute spirit with hydrocarbon oil long enough, you will end by removing all that the hydrocarbons will remove. It is simply a question of employing an apparatus which will do it most economically and in the shortest time.

As to the efficiency of the hydrocarbon process, it is clear that if the impurities are more soluble in the hydrocarbon than in the dilute spirit, they will be removed. If more soluble in the spirit than in the oil, they will not be.

Now, aldehyde is not an unfrequent constituent of crude spirit. All the patentees claim more or less that the hydrocarbon process gets out the aldehyde. But aldehyde is perfectly insoluble in the hydrocarbon oil, while it is soluble in all proportions in water and alcohol. Therefore the hydrocarbon process cannot remove it. Bang & Ruffin make their dilute spirit alkaline in order to resinify the aldehyde, but the resinification is accompanied by the formation of some volatile body of very pungent smell, so that the remedy is as bad as the disease.

As the alcohol is employed in a dilute form, it is necessary in any case to pass it through a rectifying still in order to remove the water. As the aldehyde is very volatile it comes over first, and that will be the best way of getting rid of it.

Speaking generally, I think the hydrocarbon process is a distinct advance on the charcoal process. It removes the fusel oil most effectually. Owing to the presence of aldehyde, and some very volatile ethers possibly, not removed by the hydrocarbon, there will still be some "heads" to reject, but spirit purified by the hydrocarbon process is almost entirely free from tails. Whether it will be possible to devise any process which shall be capable of removing every possible impurity from commercial alcohol without the aid of the rectifying still, I may be permitted to doubt.

DISCUSSION.

Mr. B. E. R. Newlands said that he had devoted considerable time and attention to the two processes described by Dr. Squire. He had had an opportunity of seeing the Bowick process at work at Vauxhall, and he had recently spent a week at Paris in examining the Bang & Ruffin process. The Bowick process was being worked on only a small scale, but by the Bang & Ruffin method some 10,000 liters of alcohol were being treated daily, and the process worked well. He had taken samples at various stages of the process, and having examined them carefully, had come to the conclusion that the Bang & Ruffin process produced alcohol quite equal to the best charcoal spirit. It was true that petroleum had little or no solvent action on aldehyde, but by boiling the alcohol and passing the vapors through a condenser surrounded by water at such a temperature that while the alcohol was condensed the aldehyde passed over, the head of the impurities was caught before commencing the petroleum treatment. A full consideration of the matter had convinced him that petroleum by itself would be of but little use. It must be worked concurrently with some other process, as at Paris, for removing the aldehyde and ethers, and at present he knew of no method other than distillation suitable for that purpose. If, however, the excise authorities in this country would allow petroleum to be employed on a commercial scale in the distillery, these processes might probably have a future before them, seeing that for purifying certain kinds of spirit, such as those produced from beet molasses, they would appear to be specially suitable. However, until the excise authorities allowed greater freedom of action, it would, he feared, be impossible to carry out any petroleum process in England in a distillery. In the meantime, so far as this country was concerned, the processes would have to remain in their present experimental position.

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